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Akkarakaran et al.

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(54) **DISCONTINUOUS SCHEDULING**

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(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 58 days.

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Related U.S. Application Data

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H04W 72/14 (2009.01)
H04W 72/04 (2009.01)

(52) **U.S. Cl.**
CPC ***H04W 72/14*** (2013.01); ***H04W 72/0406*** (2013.01); ***H04W 72/0446*** (2013.01); *H04W 72/042* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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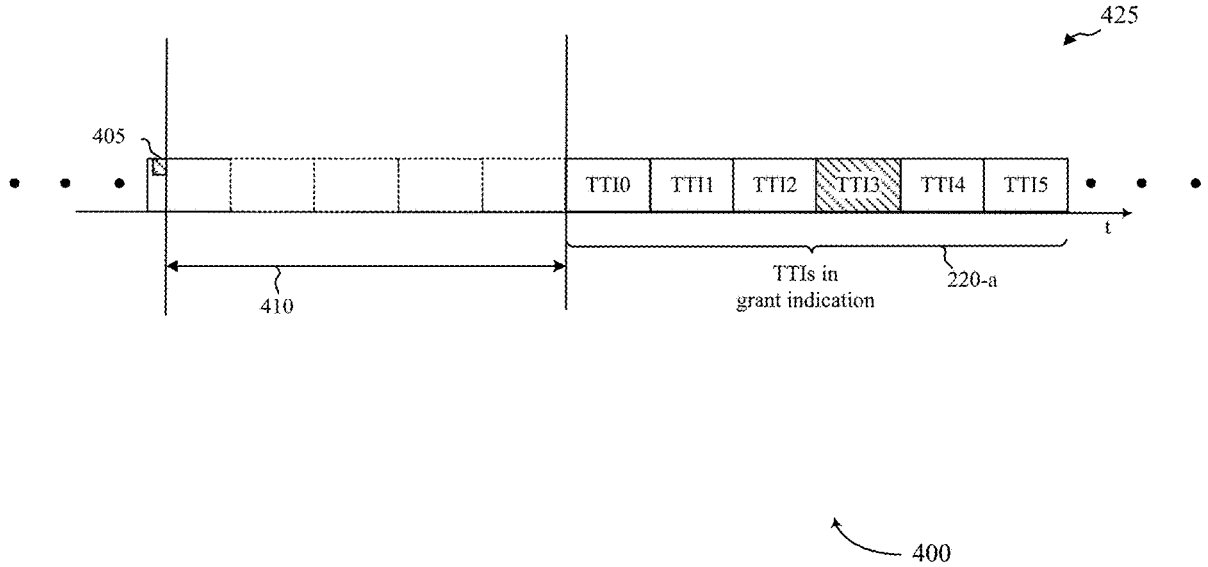
(57) **ABSTRACT**

Methods, systems, and devices for wireless communication are described that support discontinuous scheduling. A base station may transmit, to a user equipment (UE), a grant of resources of a communication channel over a multiple of aggregated TTIs. The UE may monitor a control channel for the grant of resources transmitted by base station. The base station and the UE may identify a location of an excluded TTI within the plurality of aggregated TTIs. The excluded TTI may correspond to a TTI for communicating synchronization signals, random access channel (RACH) signals, or the like. The base station may communicate with the UE via the resources of the communication channel over at least a subset of the aggregated TTIs based on the grant and the location of the excluded TTI.

72 Claims, 23 Drawing Sheets



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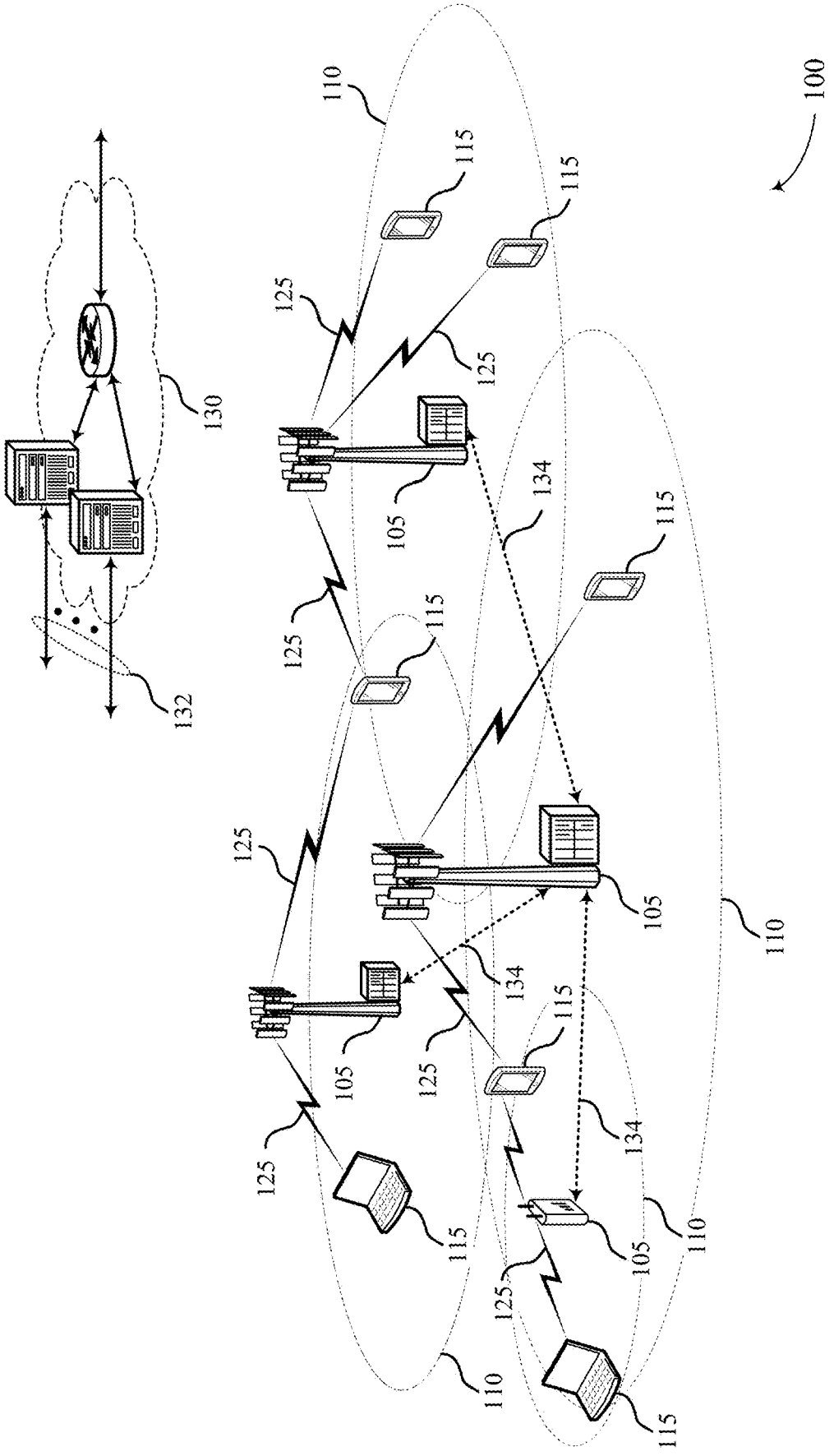
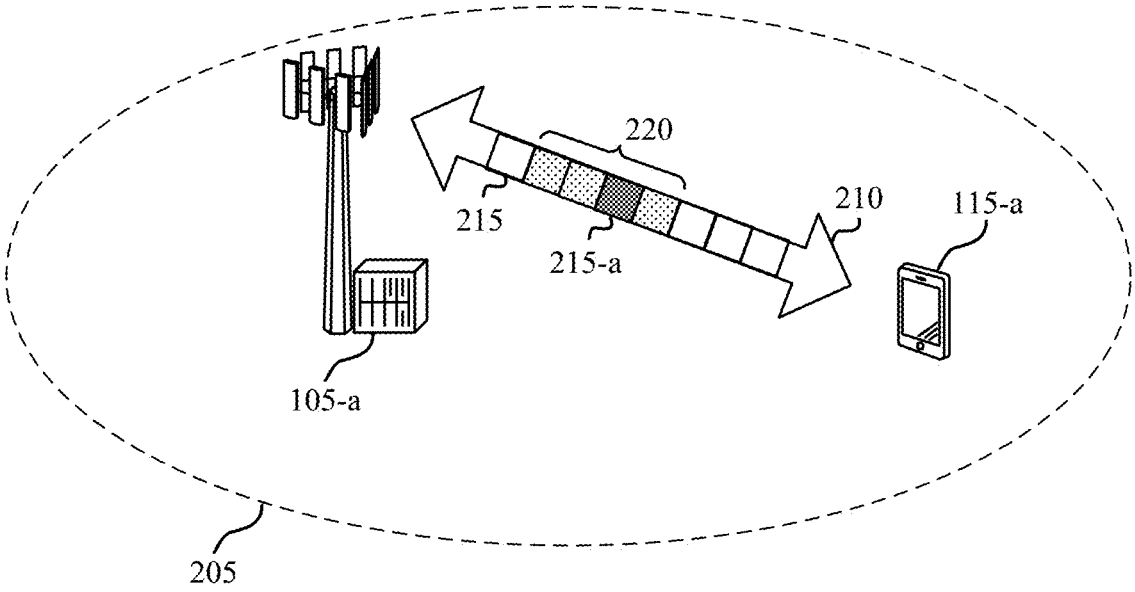


FIG. 1



200

FIG. 2

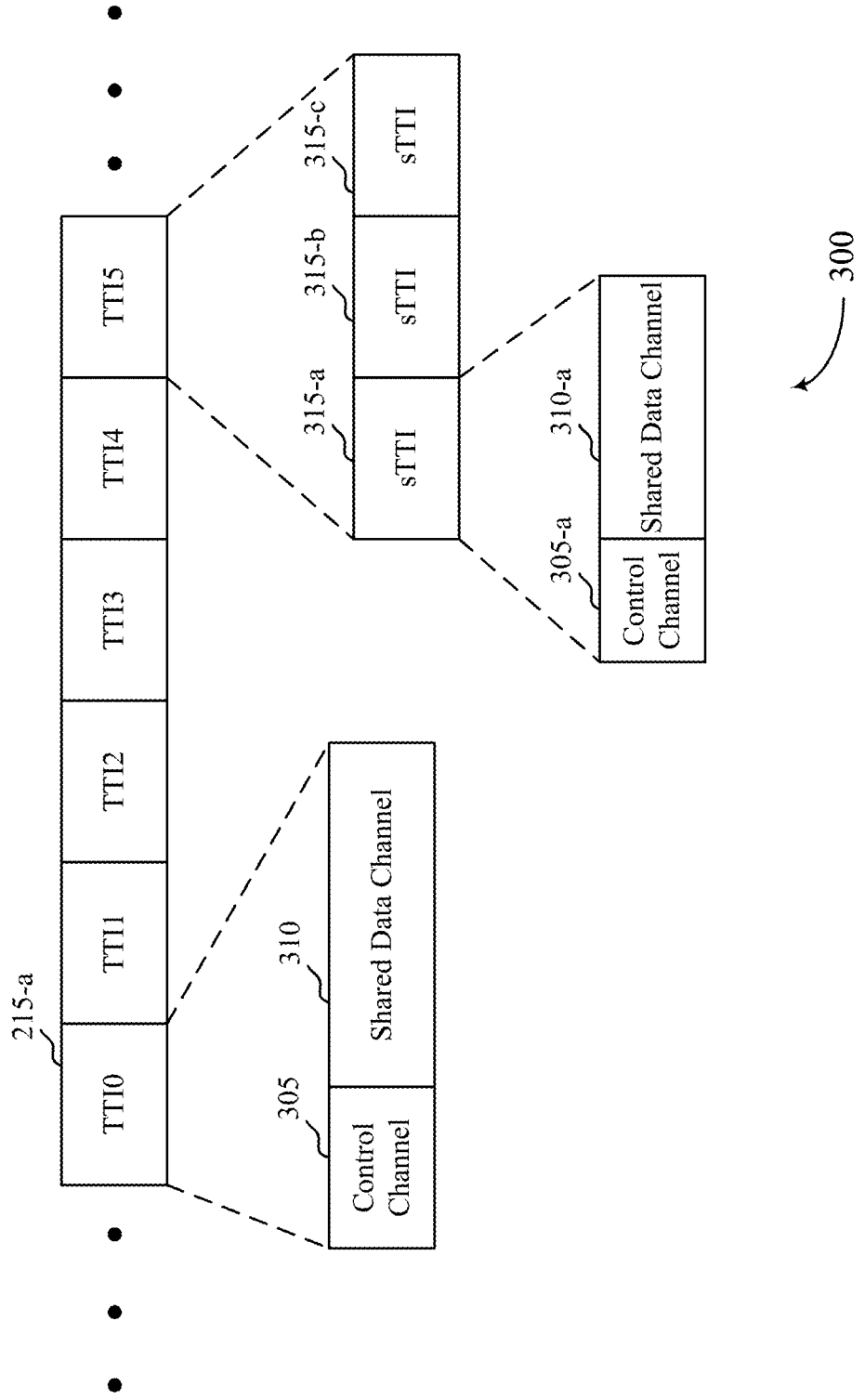
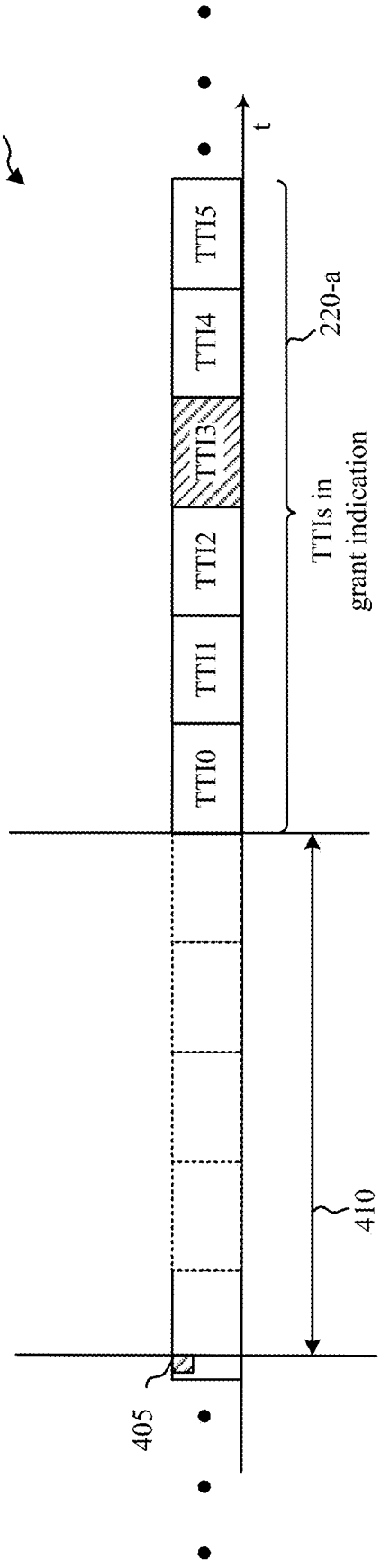

215-a
TTI0
TTI1
TTI2
TTI3
TTI4
TTI5
305
Control Channel
310
Shared Data Channel
315-a
sTTI
315-b
sTTI
315-c
sTTI
305-a
Control Channel
310-a
Shared Data Channel
300

FIG. 3


425
t
TTI5
TTI4
TTI3
TTI2
TTI1
TTI0
220-a
TTIs in grant indication
410
405

400

FIG. 4

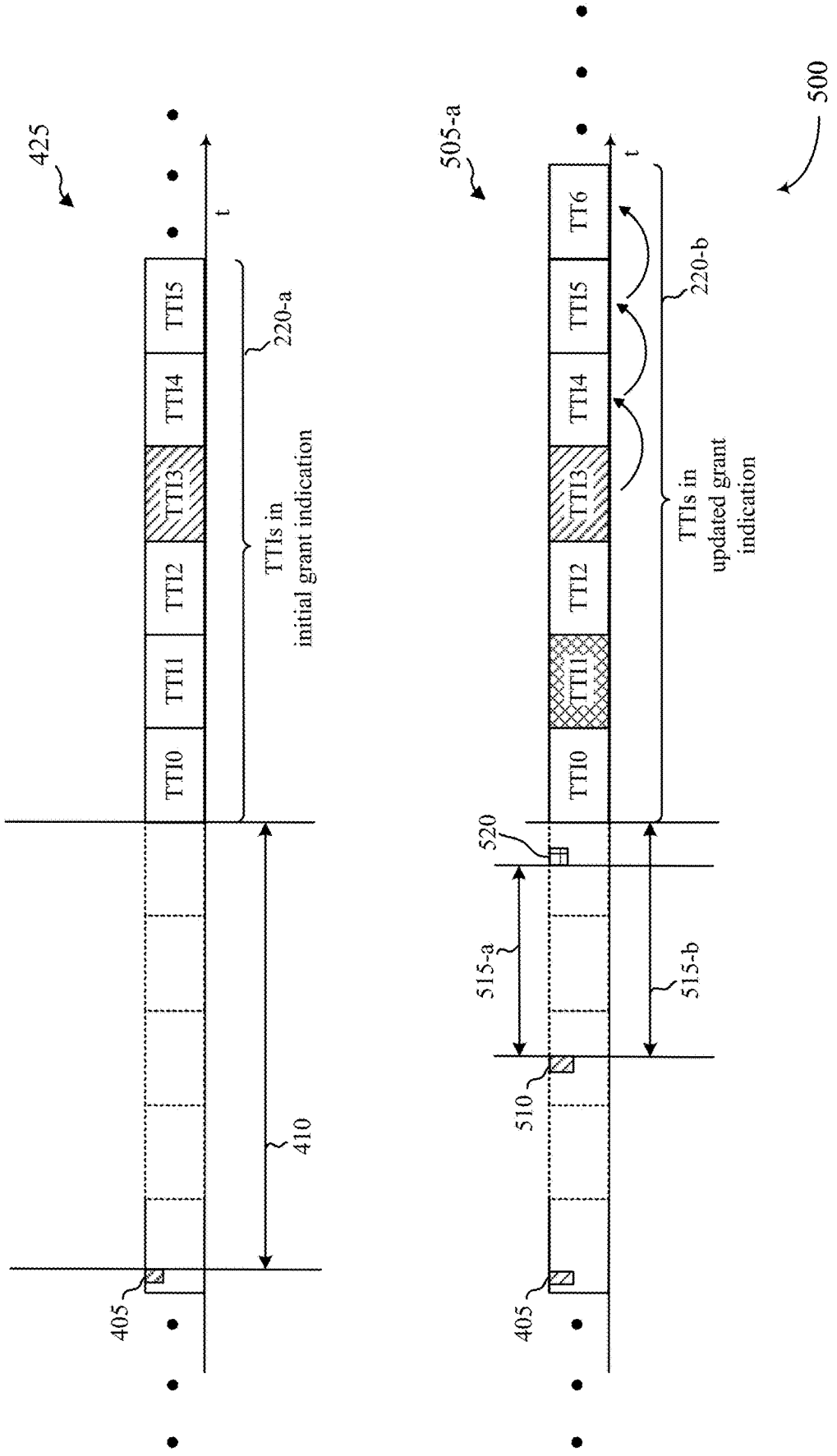

425
t
TTI0
TTI1
TTI2
TTI3
TTI4
TTI5
220-a
TTIs in
initial grant indication
410
405
500
505-a
t
TTI0
TTI1
TTI2
TTI3
TTI4
TTI5
TTI6
220-b
TTIs in
updated grant
indication
520
515-a
515-b
510
405

FIG. 5

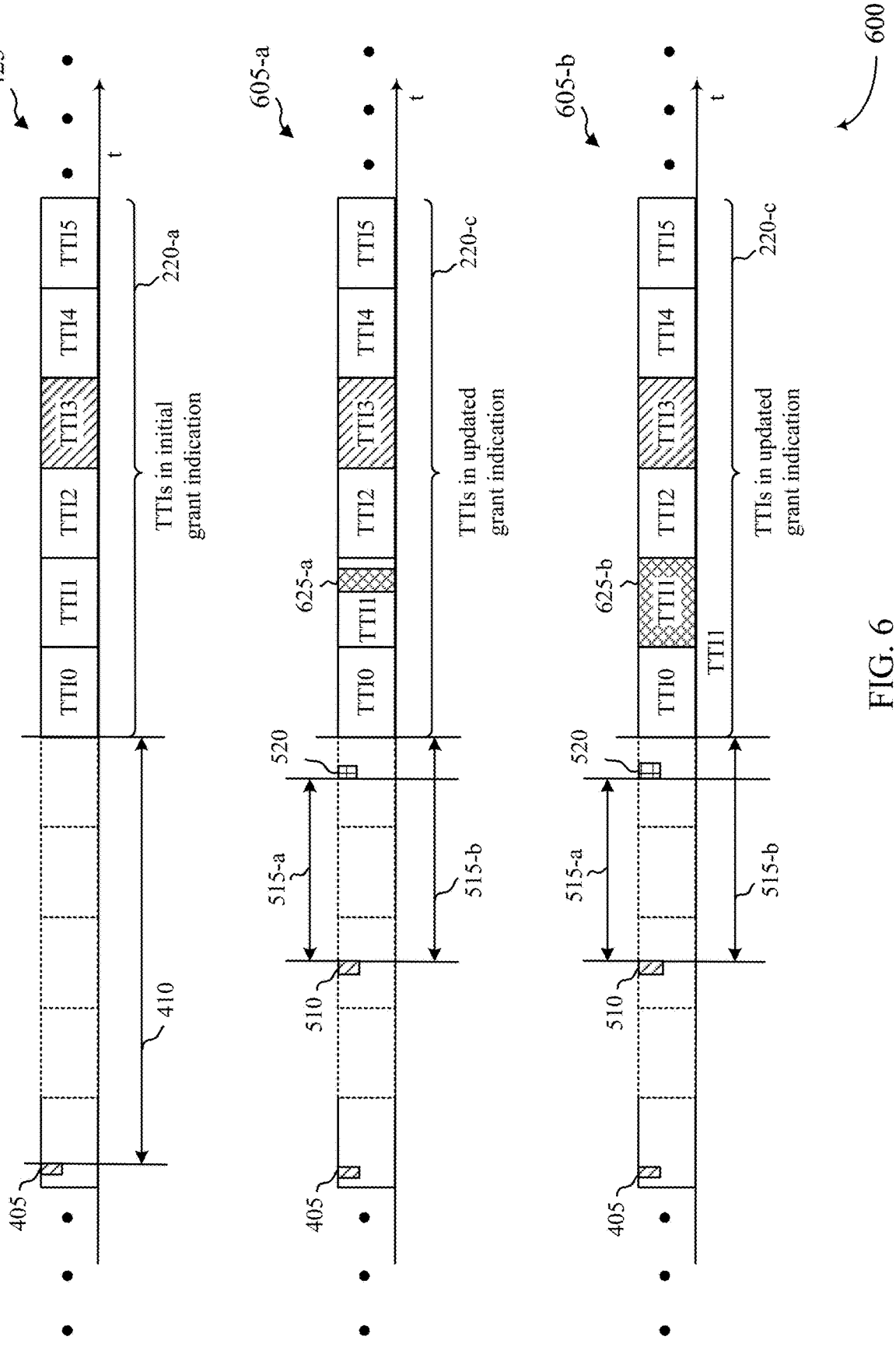

600
425
605-a
605-b
t
TTI0
TTI1
TTI2
TTI3
TTI4
TTI5
220-a
220-c
TTIs in initial grant indication
TTIs in updated grant indication
625-a
625-b
520
515-a
515-b
510
405
410

FIG. 6

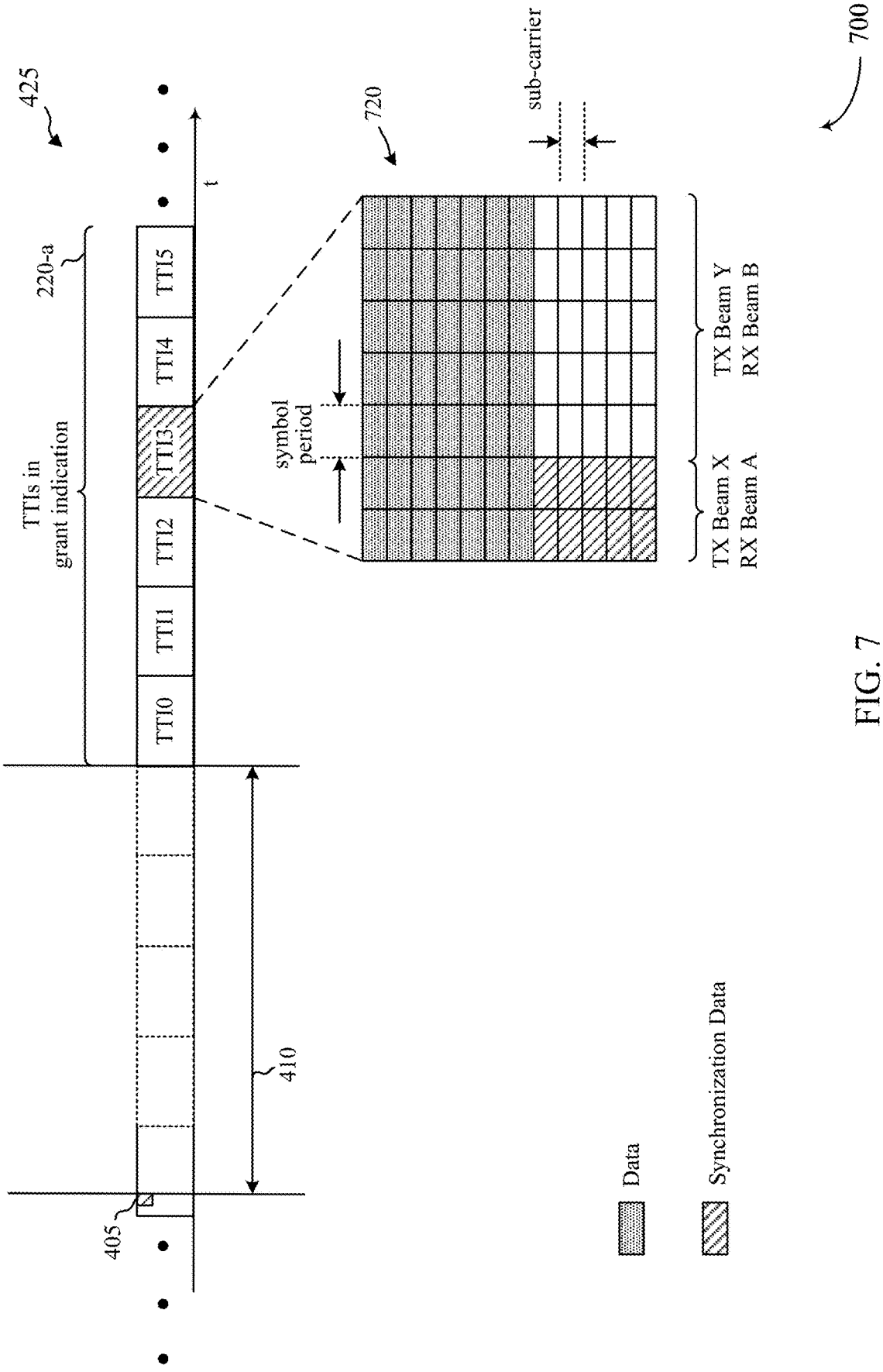

700
425
220-a
TTIs in grant indication
TTI0
TTI1
TTI2
TTI3
TTI4
TTI5
t
720
sub-carrier
symbol period
TX Beam X
RX Beam A
TX Beam Y
RX Beam B
410
405
Data
Synchronization Data

FIG. 7

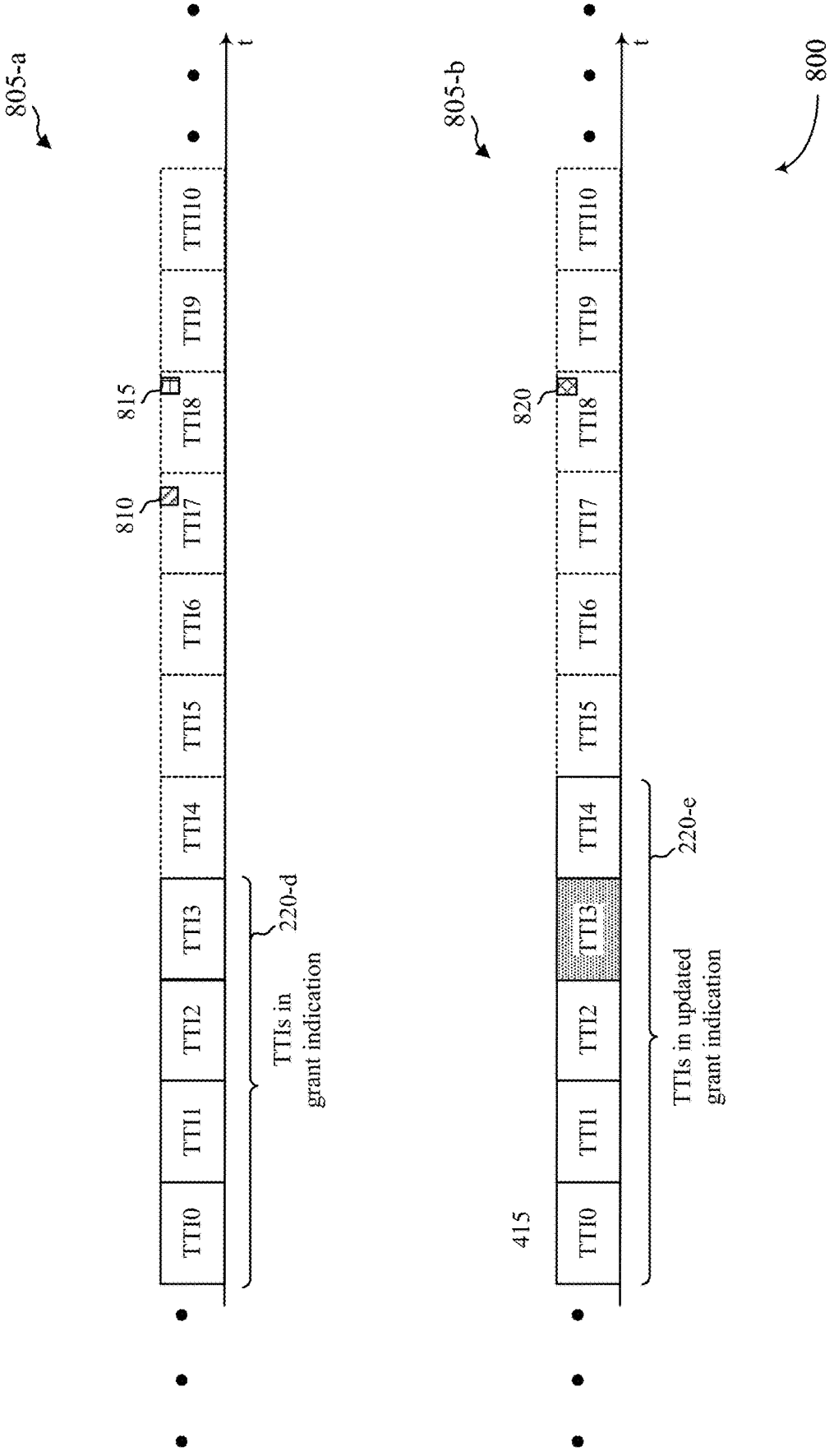

805-a
805-b
800
t
TTI0
TTI1
TTI2
TTI3
TTI4
TTI5
TTI6
TTI7
TTI8
TTI9
TTI10
810
815
820
415
220-d
220-e
TTIs in grant indication
TTIs in updated grant indication

FIG. 8

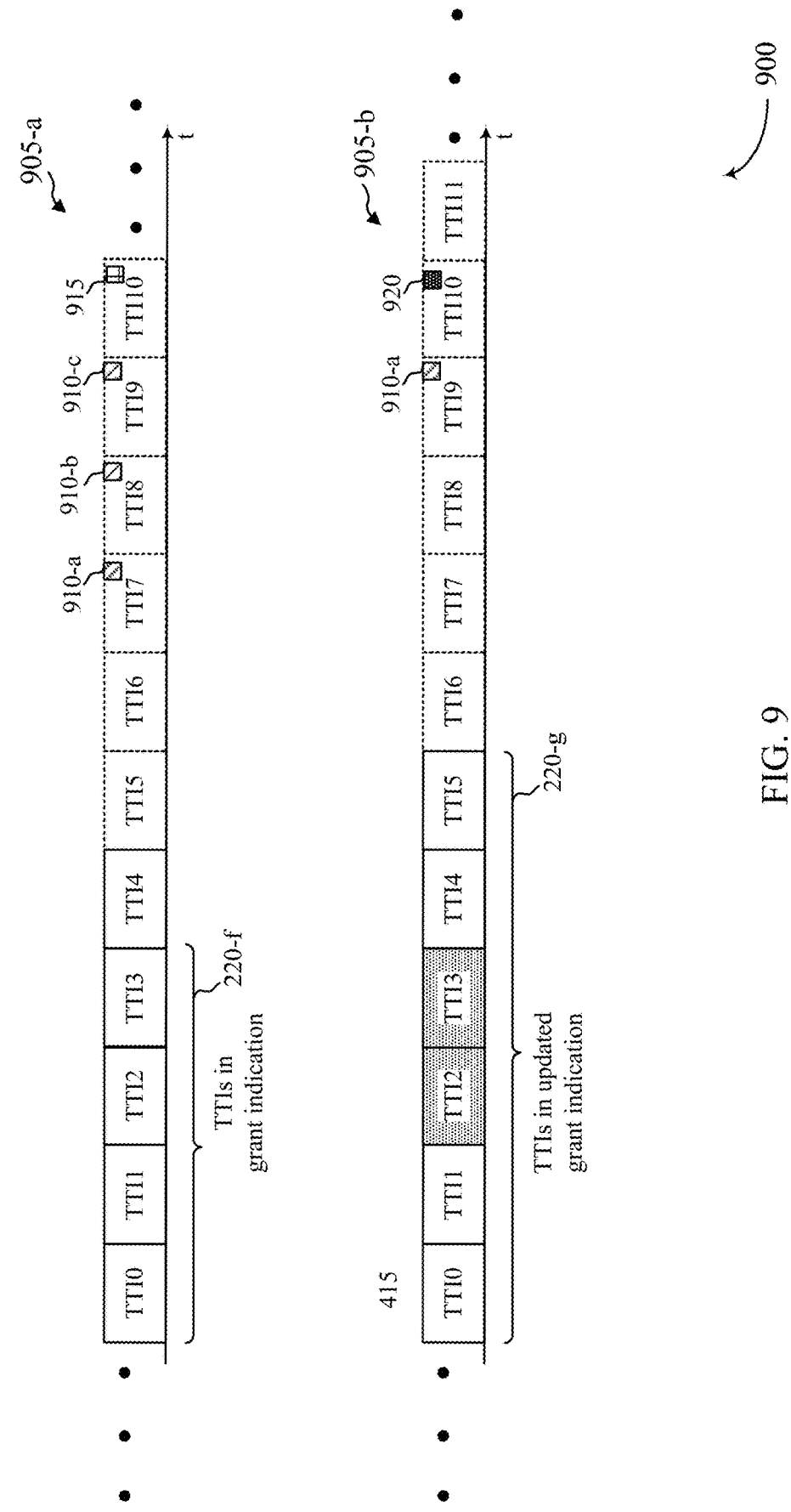

900
905-a
905-b
t
TTI0
TTI1
TTI2
TTI3
TTI4
TTI5
TTI6
TTI7
TTI8
TTI9
TTI10
TTI11
910-a
910-b
910-c
915
920
220-f
TTIs in grant indication
220-g
TTIs in updated grant indication
415

FIG. 9

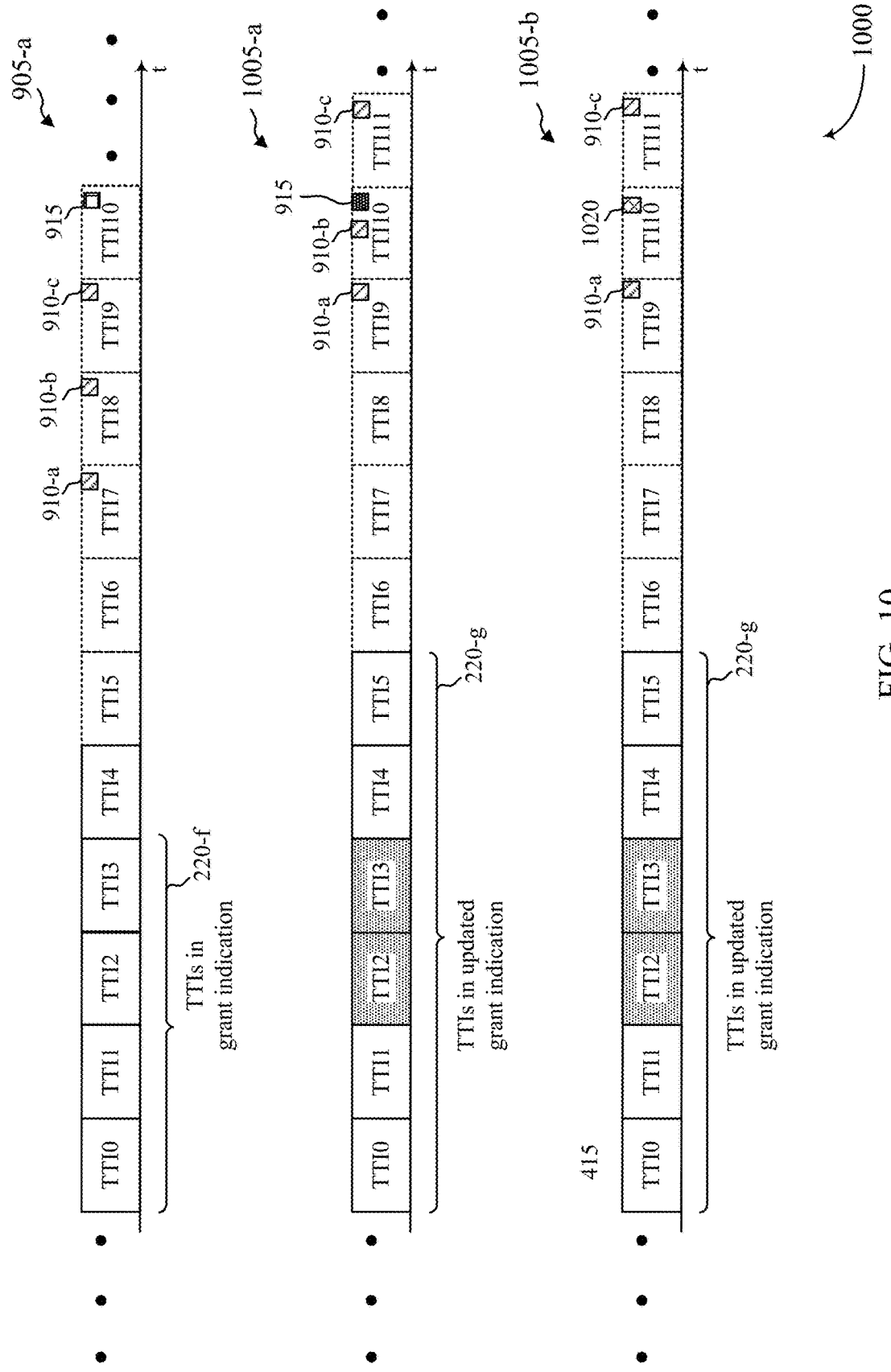

1000
905-a
1005-a
1005-b
t
TTI0
TTI1
TTI2
TTI3
TTI4
TTI5
TTI6
TTI7
TTI8
TTI9
TTI10
TTI11
910-a
910-b
910-c
915
1020
415
220-f
220-g
TTIs in grant indication
TTIs in updated grant indication

FIG. 10

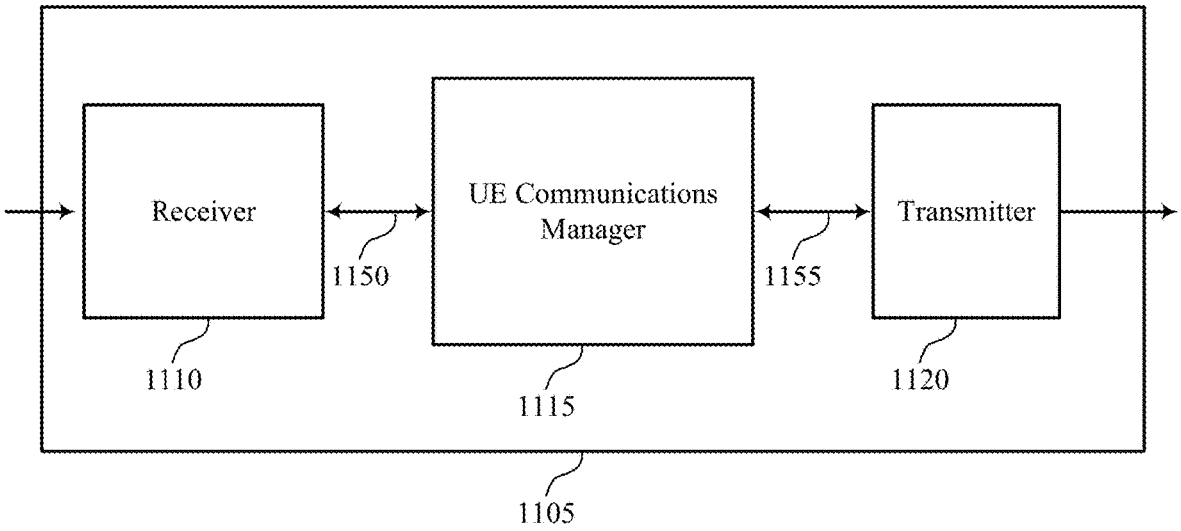

Receiver
UE Communications Manager
Transmitter
1150
1155
1110
1115
1120
1105
1100

FIG. 11

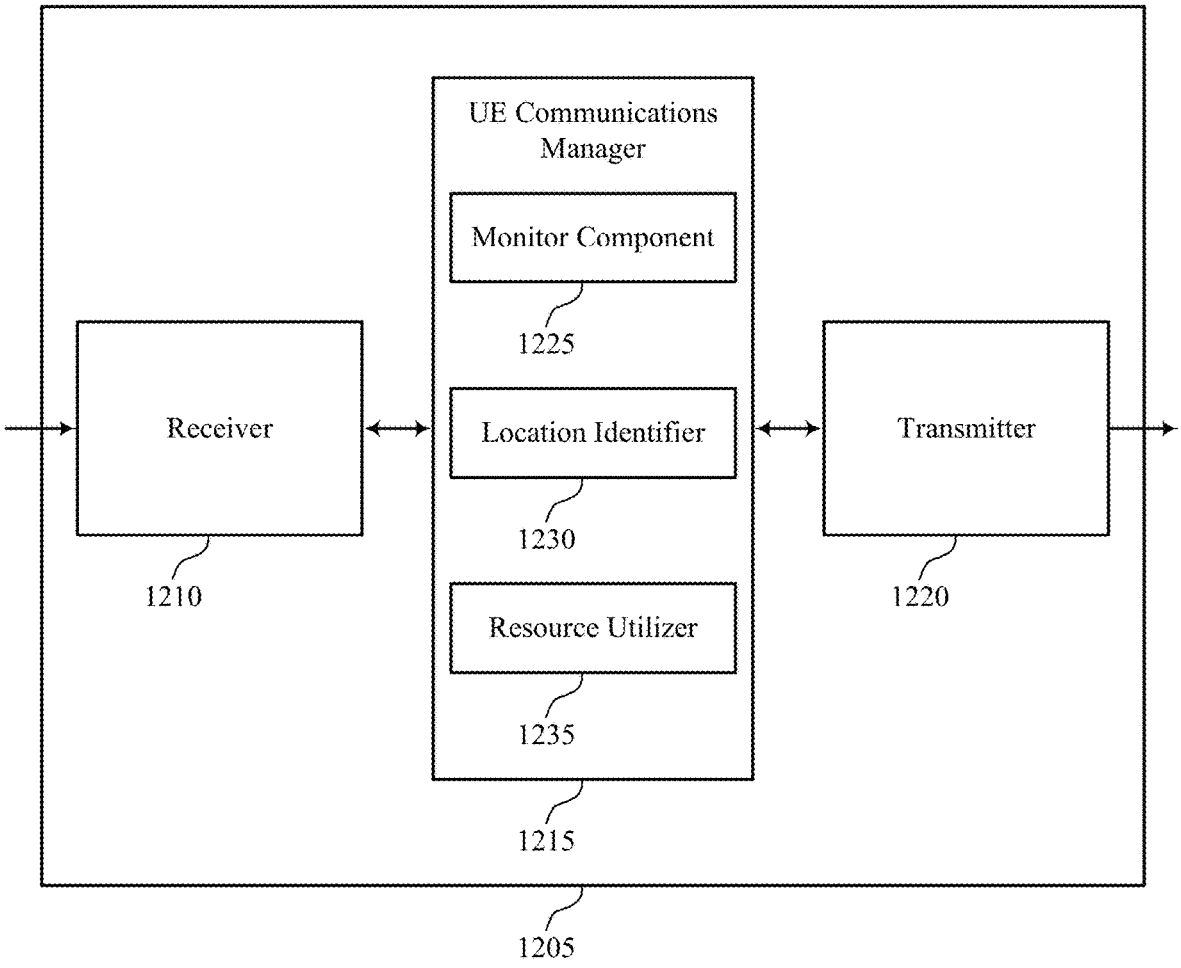

UE Communications Manager
Monitor Component
1225
Receiver
Location Identifier
Transmitter
1230
1210
1220
Resource Utilizer
1235
1215
1205
1200

FIG. 12

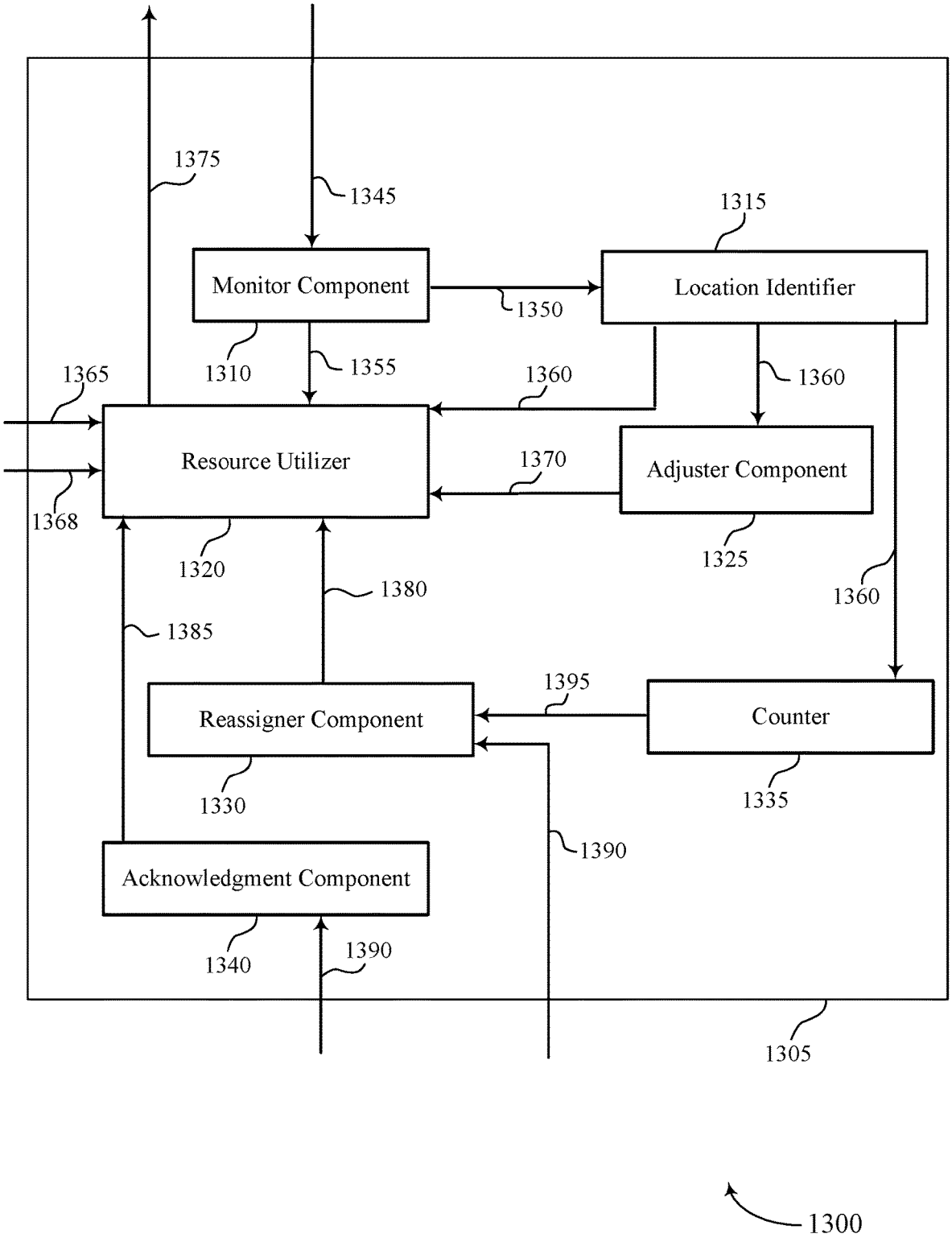

1375
1345
1315
Monitor Component
1350
Location Identifier
1310
1355
1365
1360
1360
Resource Utilizer
1370
Adjuster Component
1368
1320
1325
1380
1360
1385
1395
Reassigner Component
Counter
1330
1335
1390
Acknowledgment Component
1340
1390
1305
1300

FIG. 13

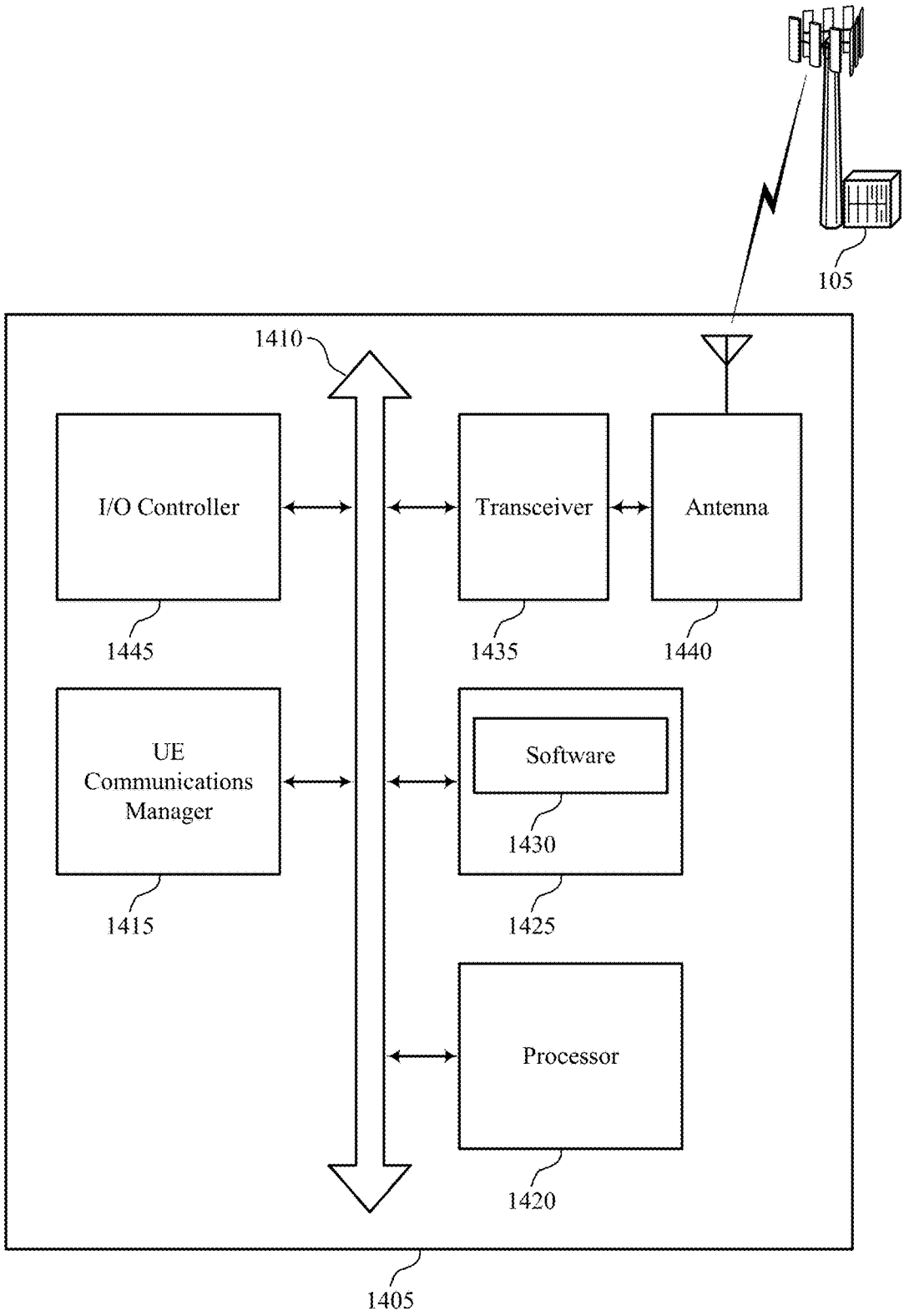

105
1410
I/O Controller
Transceiver
Antenna
1445
1435
1440
UE Communications Manager
Software
1430
1415
1425
Processor
1420
1405
1400

FIG. 14

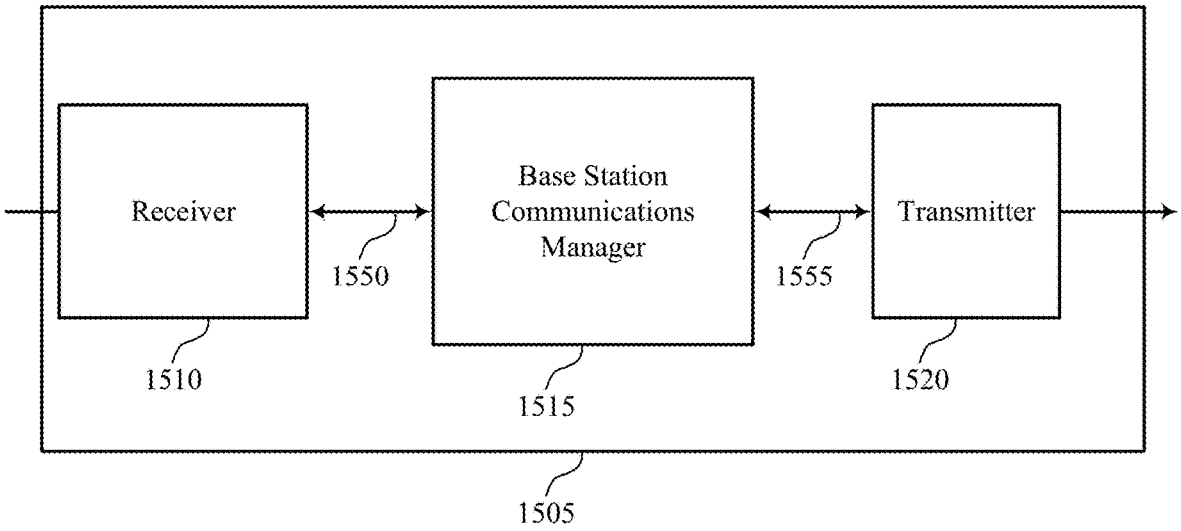

Receiver
Base Station Communications Manager
Transmitter
1550
1555
1510
1515
1520
1505
1500

FIG. 15

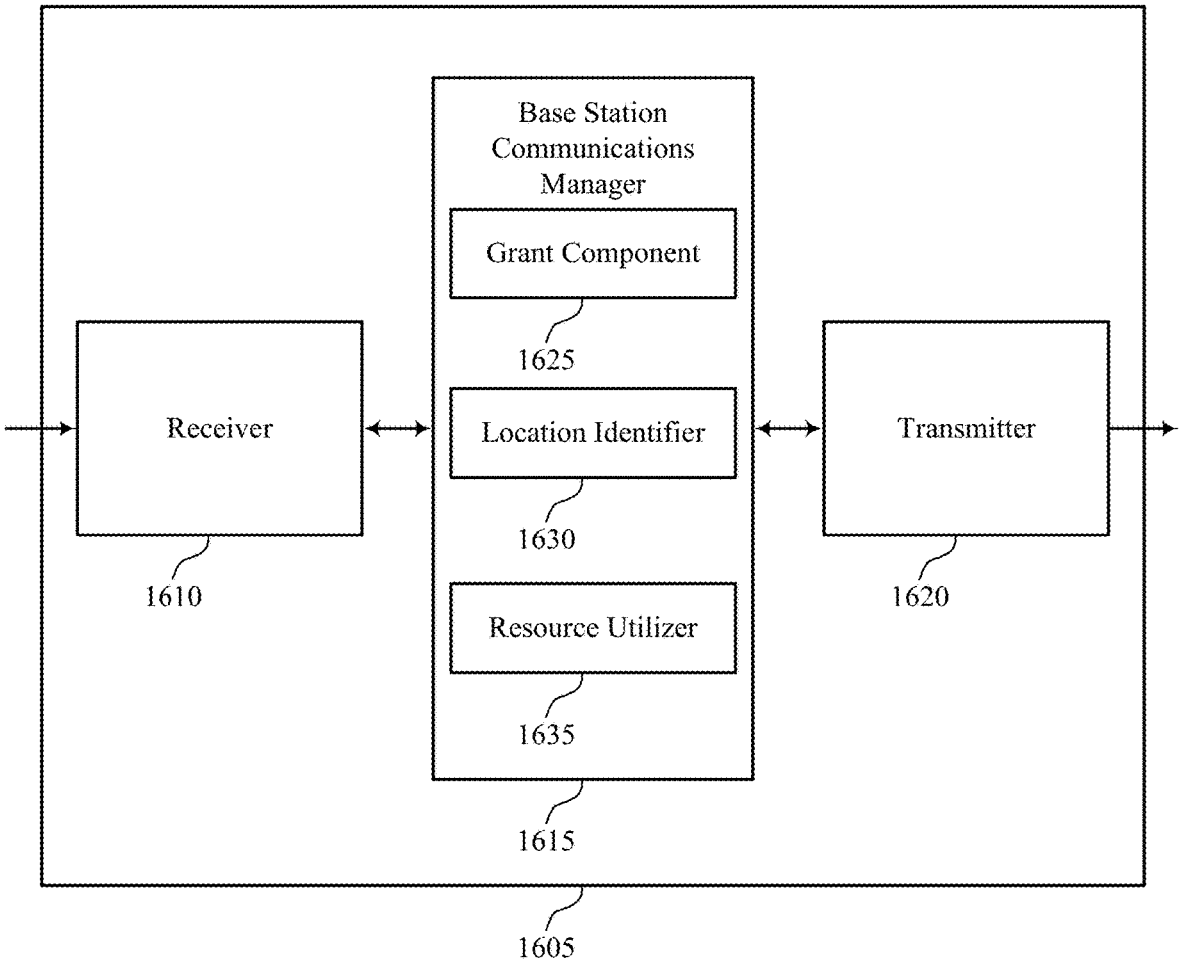

Base Station Communications Manager
Grant Component
1625
Receiver
Location Identifier
Transmitter
1630
1610
1620
Resource Utilizer
1635
1615
1605
1600

FIG. 16

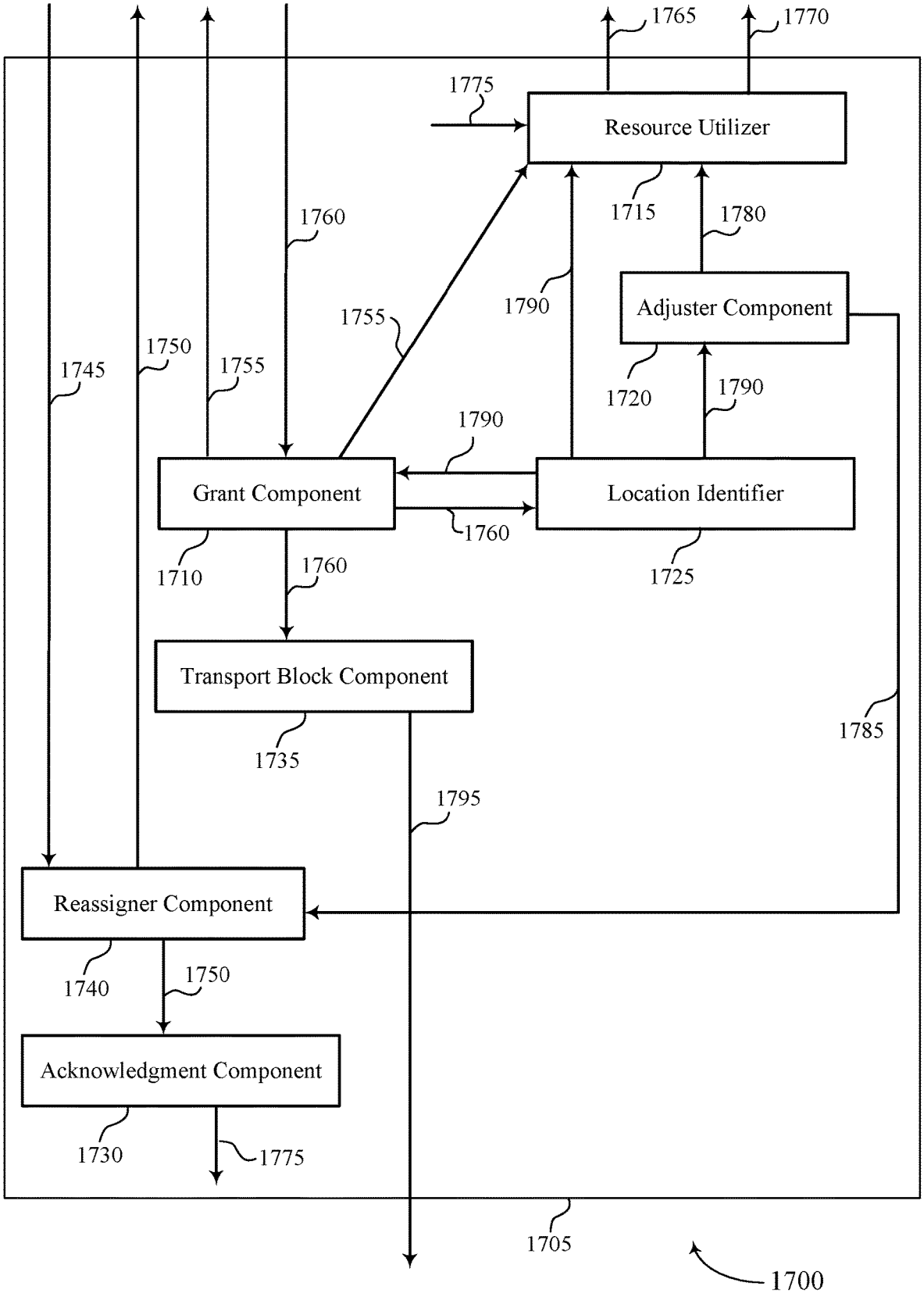

1765
1770
1775
Resource Utilizer
1760
1715
1780
1790
Adjuster Component
1755
1750
1745
1755
1720
1790
1790
Grant Component
Location Identifier
1760
1710
1760
1725
Transport Block Component
1785
1735
1795
Reassigner Component
1740
1750
Acknowledgment Component
1730
1775
1705
1700

FIG. 17

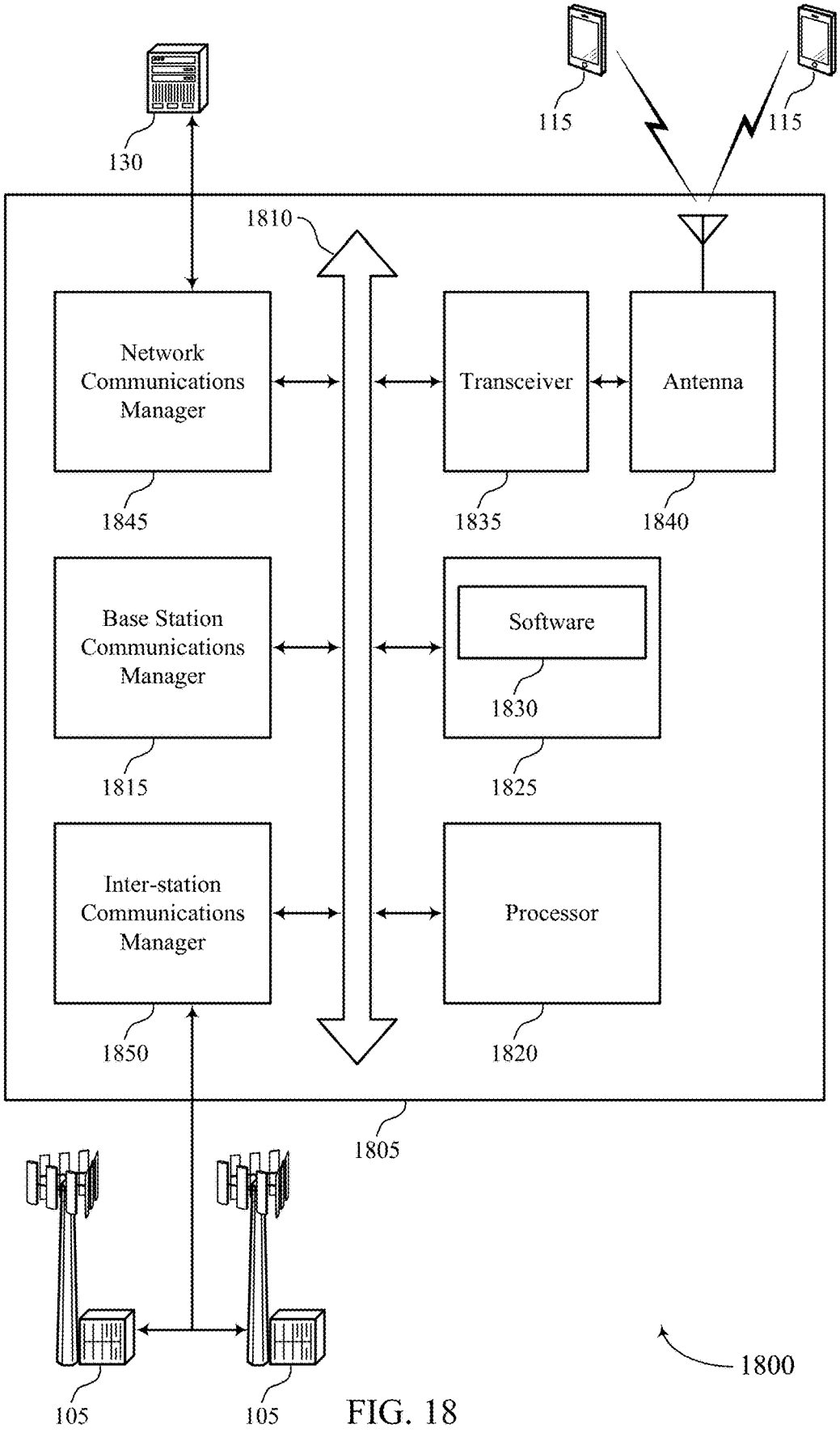

130
115
115
1810
Network Communications Manager
Transceiver
Antenna
1845
1835
1840
Base Station Communications Manager
Software
1830
1815
1825
Inter-station Communications Manager
Processor
1850
1820
1805
105
105
1800

FIG. 18

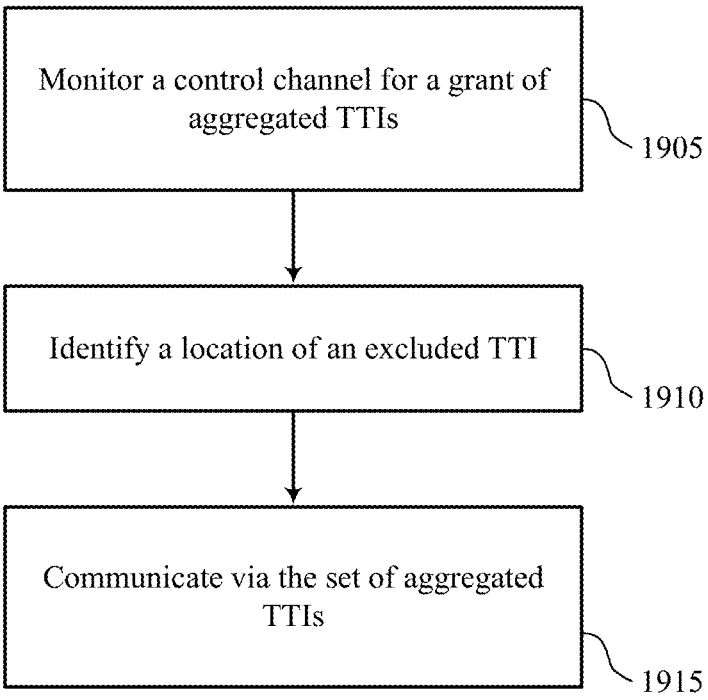

Monitor a control channel for a grant of aggregated TTIs
1905
Identify a location of an excluded TTI
1910
Communicate via the set of aggregated TTIs
1915
1900

FIG. 19

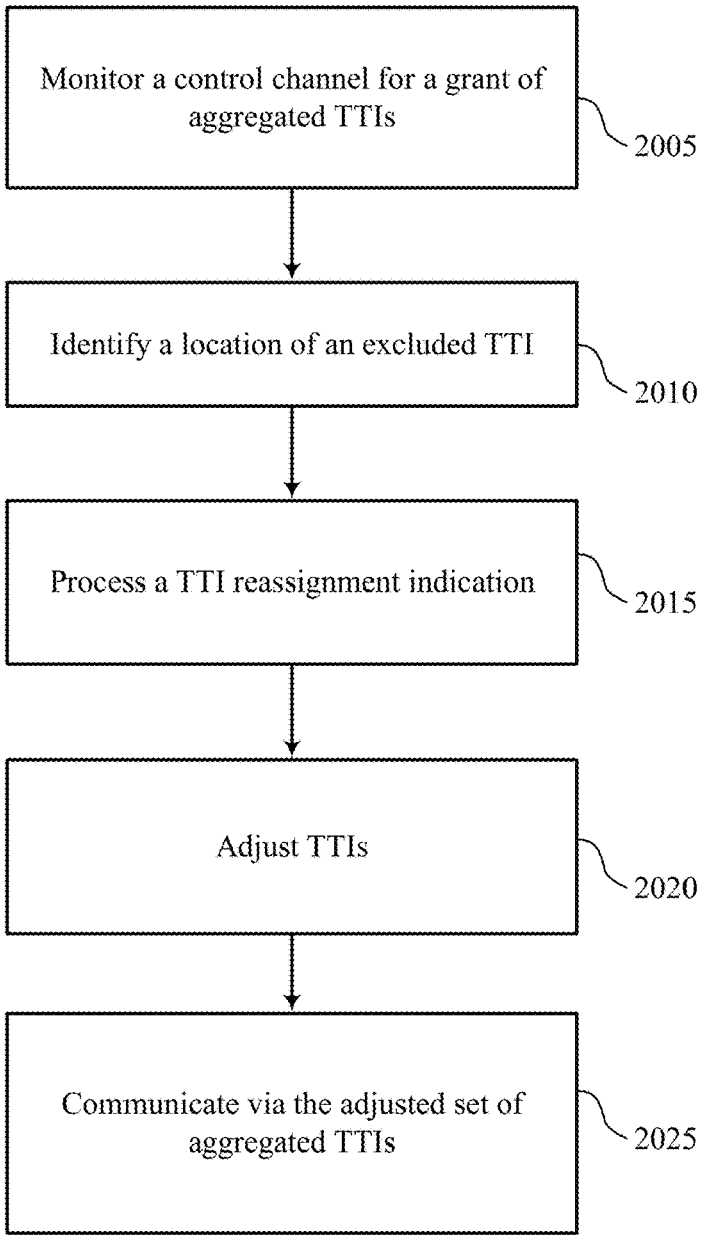

Monitor a control channel for a grant of aggregated TTIs
2005
Identify a location of an excluded TTI
2010
Process a TTI reassignment indication
2015
Adjust TTIs
2020
Communicate via the adjusted set of aggregated TTIs
2025
2000

FIG. 20

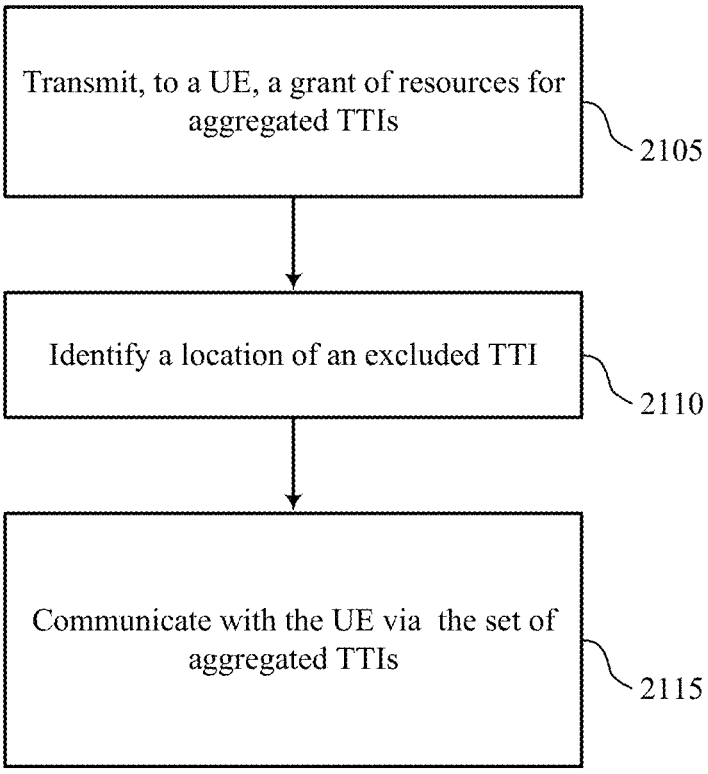

Transmit, to a UE, a grant of resources for aggregated TTIs
2105
Identify a location of an excluded TTI
2110
Communicate with the UE via the set of aggregated TTIs
2115
2100

FIG. 21

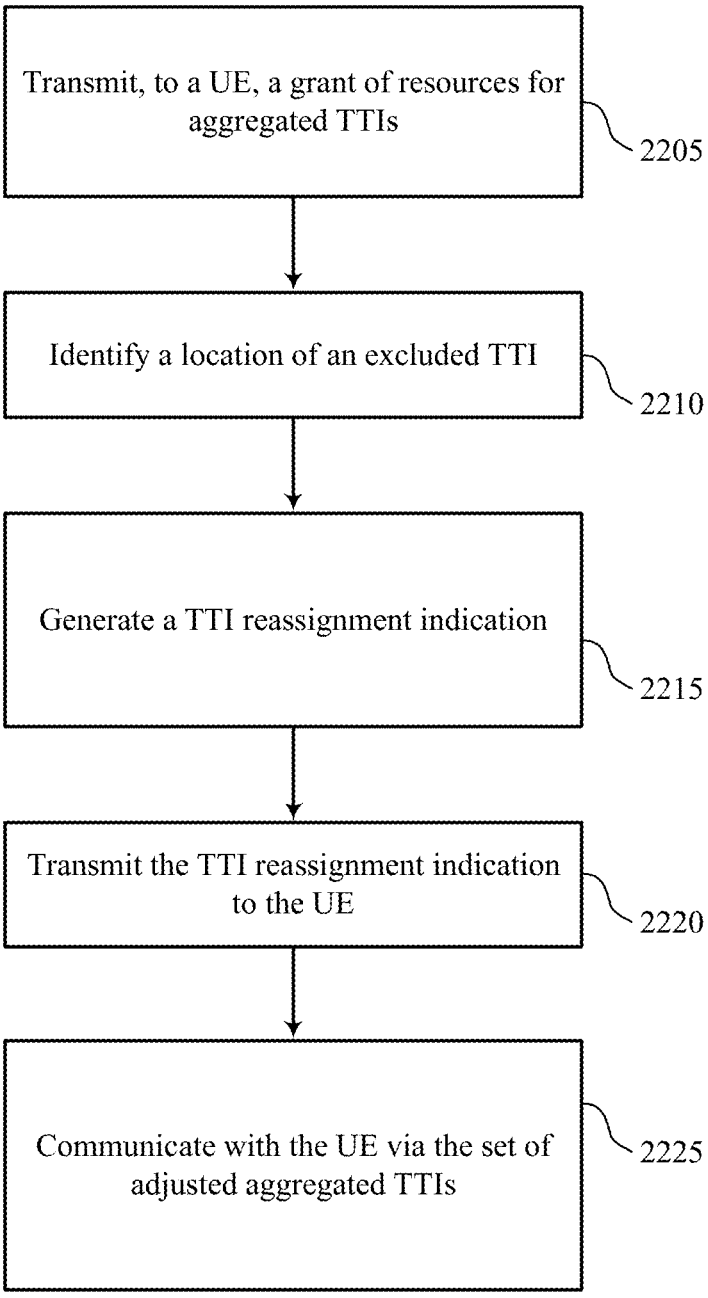

Transmit, to a UE, a grant of resources for aggregated TTIs
2205
Identify a location of an excluded TTI
2210
Generate a TTI reassignment indication
2215
Transmit the TTI reassignment indication to the UE
2220
Communicate with the UE via the set of adjusted aggregated TTIs
2225
2200

FIG. 22

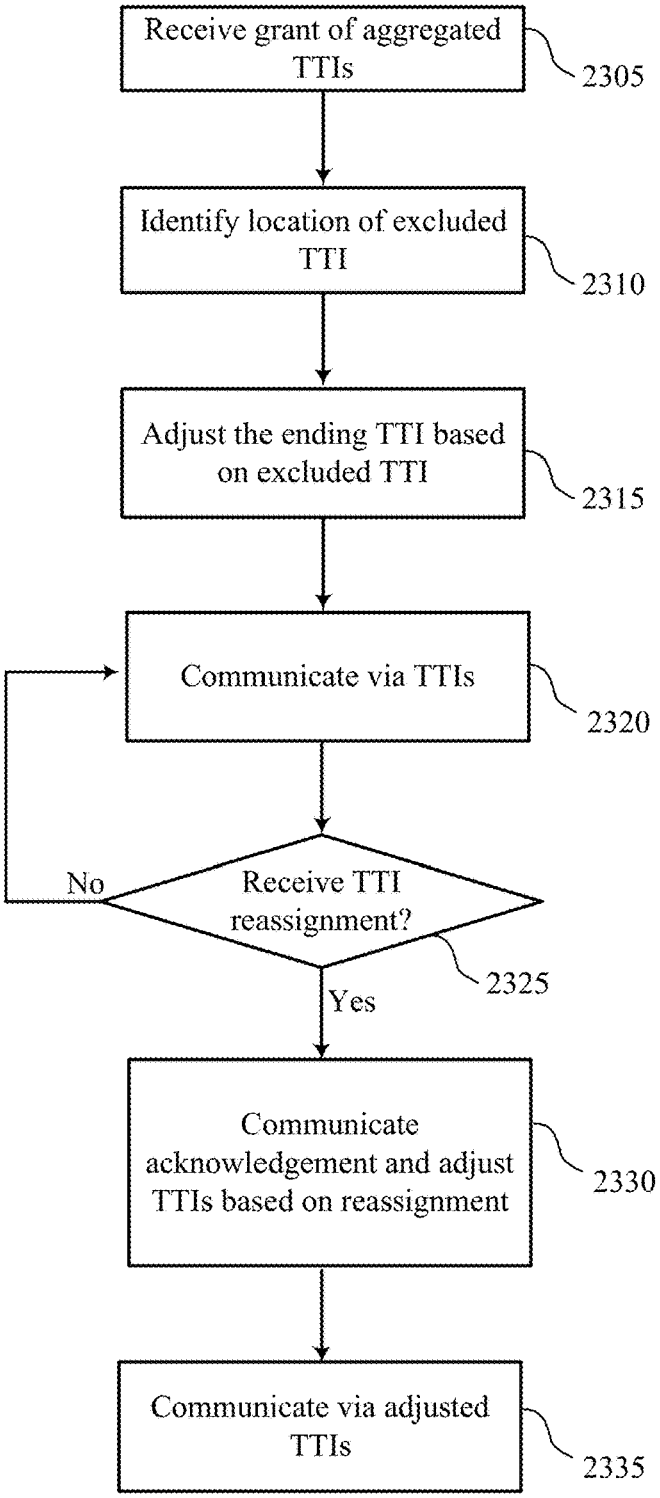

Receive grant of aggregated TTIs
2305
Identify location of excluded TTI
2310
Adjust the ending TTI based on excluded TTI
2315
Communicate via TTIs
2320
Receive TTI reassignment?
2325
No
Yes
Communicate acknowledgement and adjust TTIs based on reassignment
2330
Communicate via adjusted TTIs
2335
2300

FIG. 23

DISCONTINUOUS SCHEDULING

CROSS REFERENCES

The present Application for patent claims the benefit of U.S. Provisional Patent Application No. 62/527,951 by AKKARAKARAN et al., entitled "DISCONTINUOUS SCHEDULING IN A NEW RADIO SYSTEM," filed Jun. 30, 2017, assigned to the assignee hereof, and expressly incorporated herein.

BACKGROUND

The following relates generally to wireless communication, and more specifically to discontinuous scheduling in, for example, a new radio system.

Wireless communications systems are widely deployed to provide various types of communication content such as voice, video, packet data, messaging, broadcast, and so on. These systems may be capable of supporting communication with multiple users by sharing the available system resources (e.g., time, frequency, and power). Examples of such multiple-access systems include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, and orthogonal frequency division multiple access (OFDMA) systems, (e.g., a Long Term Evolution (LTE) system, or a New Radio (NR) system). A wireless multiple-access communications system may include a number of base stations or access network nodes, each simultaneously supporting communication for multiple communication devices, which may be otherwise known as user equipment (UE).

A base station in some Long Term Evolution (LTE) or New Radio (NR) deployments may transmit to UEs using different length transmission time intervals (TTIs) that may be reduced in length relative to legacy LTE TTIs. A reduced length TTI may be referred to as a shortened TTI (sTTI) and may support services that provide low latency with high reliability for wireless transmissions. A base station may allocate transmission resources for sTTIs to a UE that may include time and frequency resources. In some cases, reliability may be enhanced through feedback mechanisms that may provide for retransmission of unsuccessfully received transmissions, such as according to hybrid acknowledgment repeat request (HARQ) feedback techniques, for example.

New radio (NR) systems provide for slot aggregation in which a base station may grant a UE resources in one or more contiguous slots. In contiguous multi-slot transmission, a grant of resources in a set of aggregated slots may include certain slots that have a special structure, such as a synchronization slot or a random access channel (RACH) slot. Such slots may require or benefit from a different processing approach.

SUMMARY

The described techniques relate to improved methods, systems, devices, or apparatuses that support discontinuous scheduling in, for example, a new radio system. Generally, the described techniques provide for processing a grant of resources within a set of aggregated transmission time intervals (TTIs) to exclude one or more TTIs within the set (e.g., a TTI having a special structure or reserved for another purpose), and for reassignment of a TTI within the set of aggregated TTIs scheduled by a prior grant.

In accordance with the examples described herein, a base station may transmit, to a user equipment (UE), a grant of resources of a communication channel (e.g., a physical uplink shared channel (PUSCH), a physical downlink shared channel (PDSCH), a physical uplink control channel (PUCCH)) over multiple of aggregated TTIs. The UE may monitor a control channel for the grant of resources transmitted by base station. The base station and the UE may identify a location of an excluded TTI within the plurality of aggregated TTIs. The excluded TTI may correspond to a TTI for communicating synchronization signals, RACH signals, or the like. The base station may communicate with the UE via the resources of the communication channel over at least a subset of the aggregated TTIs based on the grant and the location of the excluded TTI.

A method of wireless communication by a UE is described. The method may include monitoring a control channel for a grant of resources of a communication channel over a plurality of aggregated TTIs, identifying a location of an excluded TTI within the plurality of aggregated TTIs, and communicating via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs based at least in part on the grant and the identified location of the excluded TTI.

An apparatus for wireless communication by a UE is described. The apparatus may include means for monitoring a control channel for a grant of resources of a communication channel over a plurality of aggregated TTIs, means for identifying a location of an excluded TTI within the plurality of aggregated TTIs, and means for communicating via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs based at least in part on the grant and the identified location of the excluded TTI.

Another apparatus for wireless communication by a UE is described. The apparatus may include a processor, memory in electronic communication with the processor, and instructions stored in the memory. The instructions may be operable to cause the processor to monitor a control channel for a grant of resources of a communication channel over a plurality of aggregated TTIs, identify a location of an excluded TTI within the plurality of aggregated TTIs, and communicate via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs based at least in part on the grant and the identified location of the excluded TTI.

A non-transitory computer readable medium for wireless communication by a UE is described. The non-transitory computer-readable medium may include instructions operable to cause a processor to monitor a control channel for a grant of resources of a communication channel over a plurality of aggregated TTIs, identify a location of an excluded TTI within the plurality of aggregated TTIs, and communicate via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs based at least in part on the grant and the identified location of the excluded TTI.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for adjusting an end TTI for the plurality of aggregated TTIs based at least in part on the location of the excluded TTI. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for adjusting a TTI number for the plurality of aggregated TTIs based at least in part on the location of the excluded TTI.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for maintaining a TTI count of communicated TTIs of the plurality of aggregated TTIs based at least in part on the excluded TTI in the TTI count. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for processing a TTI reassignment indication reassigning at least a portion of a first TTI of the plurality of aggregated TTIs.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for communicating an acknowledgment of the TTI reassignment indication prior to a beginning TTI of the plurality of aggregated TTIs. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for determining that the at least the portion of the first TTI may be being punctured. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for adjusting TTIs included in the plurality of aggregated TTIs based at least in part on the TTI reassignment indication.

In some examples of the method, apparatus, and non-transitory computer-readable medium described above, adjusting the TTIs comprises: determining a location of the first TTI within the plurality of aggregated TTIs. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for shifting a subset of the plurality of aggregated TTIs, that occurs after the first TTI, back by at least one TTI based at least in part on the determined location.

In some examples of the method, apparatus, and non-transitory computer-readable medium described above, communicating via the resources of the communication channel comprises: identifying a first plurality of symbols of the first TTI associated with a synchronization signal to be transmitted via a first transmit beam and a second plurality of symbols of the first TTI to be transmitted via a second transmit beam. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for receiving a first portion of a data transmission of the first TTI in the first plurality of symbols via a first receive beam associated with the first transmit beam and a second portion of the data transmission of the first TTI in the second plurality of symbols via a second receive beam associated with the second transmit beam.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for determining that a location of an acknowledgment TTI may have been changed to an updated location based at least in part on adjusting the TTIs included in the plurality of aggregated TTIs. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for communicating a merged feedback message that includes channel state information (CSI) and acknowledgement data within the updated location.

In some examples of the method, apparatus, and non-transitory computer-readable medium described above, determining that the location of the acknowledgment TTI may have changed comprises: determining that the updated location of the acknowledgment TTI may be in a same TTI as a TTI scheduled to transport the CSI. In some examples of the method, apparatus, and non-transitory computer-readable medium described above, determining that the location of the acknowledgment TTI may have changed comprises: determining that the CSI may be scheduled to be transmitted within one of the adjusted plurality of aggregated TTIs.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for determining that the TTI reassignment indication may be received after a beginning of a multi-TTI acknowledgment transmission. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for cancelling a remainder of the multi-TTI acknowledgment transmission.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for determining that the TTI reassignment indication may be received after a beginning of transmission of a multi-TTI acknowledgment transmission, wherein the merged feedback message comprises at least a portion of the multi-TTI acknowledgment transmission.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for determining that a location of an acknowledgment TTI may have changed to an updated location that overlaps with a TTI in which CSI may be scheduled for transmission. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for determining that the TTI reassignment indication may be received after a beginning of transmission of a multi-TTI acknowledgment transmission. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for transmitting the CSI and at least a portion of the multi-TTI acknowledgment transmission within the updated location of the acknowledgment TTI.

In some examples of the method, apparatus, and non-transitory computer-readable medium described above, the grant comprises a bit sequence identifying the plurality of aggregated TTIs. In some examples of the method, apparatus, and non-transitory computer-readable medium described above, the grant comprises an index that corresponds to one of a plurality of configurations for the plurality of aggregated TTIs. In some examples of the method, apparatus, and non-transitory computer-readable medium described above, at least some of the plurality of aggregated TTIs may be non-contiguous in time.

A method of wireless communication by a base station is described. The method may include transmitting, to a UE, a grant of resources of a communication channel over a plurality of aggregated TTIs, identifying a location of an excluded TTI within the plurality of aggregated TTIs, and communicating with the UE via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs based at least in part on the grant and the location of the excluded TTI.

An apparatus for wireless communication by a base station is described. The apparatus may include means for transmitting, to a UE, a grant of resources of a communi-

cation channel over a plurality of aggregated TTIs, means for identifying a location of an excluded TTI within the plurality of aggregated TTIs, and means for communicating with the UE via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs based at least in part on the grant and the location of the excluded TTI.

Another apparatus for wireless communication by a base station is described. The apparatus may include a processor, memory in electronic communication with the processor, and instructions stored in the memory. The instructions may be operable to cause the processor to transmit, to a UE, a grant of resources of a communication channel over a plurality of aggregated TTIs, identify a location of an excluded TTI within the plurality of aggregated TTIs, and communicate with the UE via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs based at least in part on the grant and the location of the excluded TTI.

A non-transitory computer readable medium for wireless communication by a base station is described. The non-transitory computer-readable medium may include instructions operable to cause a processor to transmit, to a UE, a grant of resources of a communication channel over a plurality of aggregated TTIs, identify a location of an excluded TTI within the plurality of aggregated TTIs, and communicate with the UE via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs based at least in part on the grant and the location of the excluded TTI.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for adjusting an end TTI for the plurality of aggregated TTIs based at least in part on the location of the excluded TTI. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for adjusting a TTI number for the plurality of aggregated TTIs based at least in part on the location of the excluded TTI.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for generating a TTI reassignment indication reassigning at least a portion of a first TTI of the plurality of aggregated TTIs. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for adjusting TTIs included in the plurality of aggregated TTIs based at least in part on the TTI reassignment indication.

In some examples of the method, apparatus, and non-transitory computer-readable medium described above, adjusting the TTIs comprises: determining a location of the first TTI within the plurality of aggregated TTIs. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for shifting a subset of the plurality of aggregated TTIs, that occurs after the first TTI, back by at least one TTI based at least in part on the determined location.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for identifying a first plurality of symbols of the first TTI associated with a synchronization signal to be transmitted via a first transmit beam and a second plurality of symbols of the first TTI to be transmitted via a second transmit beam.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for transmitting a first portion of a data transmission of the first TTI in the first plurality of symbols via the first transmit beam and a second portion of the data transmission of the first TTI in the second plurality of symbols via the second transmit beam.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for communicating a merged feedback message that includes channel state information (CSI) and acknowledgement data. In some examples of the method, apparatus, and non-transitory computer-readable medium described above, generating the TTI reassignment indication comprises: generating the TTI reassignment indication based at least in part on determining that a capability of the UE satisfies a threshold. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for transmitting the TTI reassignment indication to the UE.

In some examples of the method, apparatus, and non-transitory computer-readable medium described above, determining that the capability of the UE satisfies the threshold comprises: determining that a response time of the UE satisfies the threshold. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for receiving an acknowledgment of the TTI reassignment indication prior to a beginning TTI of the plurality of aggregated TTIs.

Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for communicating a transport block size that excludes the first TTI from a calculation of the transport block size. Some examples of the method, apparatus, and non-transitory computer-readable medium described above may further include processes, features, means, or instructions for determining that the at least the portion of the first TTI may be being punctured.

In some examples of the method, apparatus, and non-transitory computer-readable medium described above, the grant comprises a bit sequence identifying the plurality of aggregated TTIs. In some examples of the method, apparatus, and non-transitory computer-readable medium described above, the grant comprises an index that corresponds to one of a plurality of configurations for the plurality of aggregated TTIs. In some examples of the method, apparatus, and non-transitory computer-readable medium described above, at least some of the plurality of aggregated TTIs may be non-contiguous in time.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an example of a system for wireless communication that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIG. **2** illustrates an example diagram of a wireless communications system that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIG. **3** illustrates an example diagram of transmission time intervals (TTIs) that support discontinuous scheduling in accordance with aspects of the present disclosure.

FIG. **4** illustrates an example diagram of a set of aggregated TTIs that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIG. **5** illustrates an example diagram of TTI reassignment with rate-matching that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIG. **6** illustrates an example diagram of TTI reassignment with puncturing that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIG. **7** illustrates an example diagram of multiple beams that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIG. **8** illustrates an example diagram of merging channel state information and acknowledgment data that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIG. **9** illustrates an example diagram of merging channel state information and acknowledgment data that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIG. **10** illustrates an example diagram of merging channel state information and acknowledgment data that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIGS. **11** through **13** show block diagrams of a device that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIG. **14** illustrates a block diagram of a system including a UE that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIGS. **15** through **17** show block diagrams of a device that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIG. **18** illustrates a block diagram of a system including a base station that supports discontinuous scheduling in accordance with aspects of the present disclosure.

FIGS. **19** through **23** illustrate methods for discontinuous scheduling in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

The described techniques relate to improved methods, systems, devices, or apparatuses that support discontinuous scheduling. Generally, the described techniques provide for processing a grant of resources within a set of aggregated transmission time intervals (TTIs), and for reassignment of a TTI scheduled by a prior grant.

New radio (NR) systems provide for slot aggregation in which a base station may grant a user equipment (UE) resources in one or more slots. In some cases, an encoded packet may be modulated onto resource blocks in multiple slots, or a one-slot transmission may be repeated in multiple slots. In contiguous multi-slot transmission, a grant of resources in a set of aggregated slots may include certain slots that have a special structure. Slots having a special structure may include, for example, slots containing a synchronization channel on the downlink (e.g., a sync slot) and a random access channel on the uplink (e.g., a RACH slot). Slots having a special structure may not be available for data communication. Thus, such slots may need to be excluded from the set of aggregated slots. Conventional NR systems lack techniques for indicating or identifying which slots are to be excluded from the set of aggregated slots.

Moreover, a slot that may be included in a set of aggregated slots in an initial grant may subsequently be identified as a slot having a special structure. Such slots may include slots reserved for forward compatibility (e.g., slots reserved for transmissions that are only allowed for future releases), slots containing Ultra-Reliable and Low-Latency Communications (URLLC) data, or the like. Conventional NR systems lack techniques for indicating or identifying, after an initial grant, which slots are to be excluded from the previously granted set of aggregated slots.

In accordance with the examples described herein, a base station may transmit, to a UE, a grant of resources of a communication channel over multiple aggregated TTIs. The UE may monitor a control channel for the grant of resources transmitted by base station. The base station and the UE may identify a location of an excluded TTI within the plurality of aggregated TTIs. The excluded TTI may correspond to a TTI for communicating synchronization signals, RACH signals, or the like. The base station may communicate with the UE via the resources of the communication channel over at least a subset of the aggregated TTIs based on the grant and the location of the excluded TTI.

Aspects of the disclosure are initially described in the context of a wireless communications system. The wireless communications system may provide for processing a grant of resources within a set of aggregated TTIs, and for reassignment of a TTI scheduled by a prior grant. Aspects of the disclosure are further illustrated by and described with reference to apparatus diagrams, system diagrams, and flowcharts that relate to discontinuous scheduling.

FIG. **1** illustrates an example of a wireless communications system **100** in accordance with various aspects of the present disclosure. The wireless communications system **100** includes base stations **105**, UEs **115**, and a core network **130**. In some examples, the wireless communications system **100** may be a Long Term Evolution (LTE), LTE-Advanced (LTE-A) network, or a New Radio (NR) network. In some cases, wireless communications system **100** may support enhanced broadband communications, ultra-reliable (i.e., mission critical) communications, low latency communications, and communications with low-cost and low-complexity devices.

In accordance with the examples described herein, a base station **105** may transmit, to a UE **115**, a grant of resources of a communication channel over multiple of aggregated TTIs. The grant of resources may be used for uplink transmission, downlink transmission, or both, within the resources of the communication channel over the multiple aggregated TTIs. The UE **115** may monitor a control channel for the grant of resources transmitted by base station **105**. The base station **105** and the UE **115** may identify a location of an excluded TTI within the aggregated TTIs. The excluded TTI may correspond to a TTI for communicating synchronization signals, RACH signals, or the like. The base station **105** may communicate with the UE **115** via the communication channel resources over at least a subset of the aggregated TTIs based on the grant and the location of the excluded TTI.

Base stations **105** may wirelessly communicate with UEs **115** via one or more base station antennas. Each base station **105** may provide communication coverage for a respective geographic coverage area **110**. Communication links **125** shown in wireless communications system **100** may include uplink transmissions from a UE **115** to a base station **105**, or downlink transmissions, from a base station **105** to a UE **115**. Control information and data may be multiplexed on an uplink channel or downlink according to various techniques. Control information and data may be multiplexed on a downlink channel, for example, using time division multiplexing (TDM) techniques, frequency division multiplexing

(FDM) techniques, or hybrid TDM-FDM techniques. In some examples, the control information transmitted during a transmission time interval (TTI) of a downlink channel may be distributed between different control regions in a cascaded manner (e.g., between a common control region and one or more UE-specific control regions).

UEs **115** may be dispersed throughout the wireless communications system **100**, and each UE **115** may be stationary or mobile. A UE **115** may also be referred to as a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology. A UE **115** may also be a cellular phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a tablet computer, a laptop computer, a cordless phone, a personal electronic device, a handheld device, a personal computer, a wireless local loop (WLL) station, an Internet of Things (IoT) device, an Internet of Everything (IoE) device, a machine type communication (MTC) device, an appliance, an automobile, or the like.

In some cases, a UE **115** may also be able to communicate directly with other UEs (e.g., using a peer-to-peer (P2P) or device-to-device (D2D) protocol). One or more of a group of UEs **115** utilizing D2D communications may be within the coverage area **110** of a cell. Other UEs **115** in such a group may be outside the coverage area **110** of a cell, or otherwise unable to receive transmissions from a base station **105**. In some cases, groups of UEs **115** communicating via D2D communications may utilize a one-to-many (1:M) system in which each UE **115** transmits to every other UE **115** in the group. In some cases, a base station **105** facilitates the scheduling of resources for D2D communications. In other cases, D2D communications are carried out independent of a base station **105**.

Some UEs **115**, such as MTC or IoT devices, may be low cost or low complexity devices, and may provide for automated communication between machines, i.e., Machine-to-Machine (M2M) communication. M2M or MTC may refer to data communication technologies that allow devices to communicate with one another or a base station without human intervention. For example, M2M or MTC may refer to communications from devices that integrate sensors or meters to measure or capture information and relay that information to a central server or application program that can make use of the information or present the information to humans interacting with the program or application. Some UEs **115** may be designed to collect information or enable automated behavior of machines. Examples of applications for MTC devices include smart metering, inventory monitoring, water level monitoring, equipment monitoring, healthcare monitoring, wildlife monitoring, weather and geological event monitoring, fleet management and tracking, remote security sensing, physical access control, and transaction-based business charging.

In some cases, an MTC device may operate using half-duplex (one-way) communications at a reduced peak rate. MTC devices may also be configured to enter a power saving "deep sleep" mode when not engaging in active communications. In some cases, MTC or IoT devices may be designed to support mission critical functions and wireless communications system may be configured to provide ultra-reliable communications for these functions.

Base stations **105** may communicate with the core network **130** and with one another. For example, base stations **105** may interface with the core network **130** through backhaul links **132** (e.g., S1, etc.). Base stations **105** may communicate with one another over backhaul links **134** (e.g., X2, etc.) either directly or indirectly (e.g., through core network **130**). Base stations **105** may perform radio configuration and scheduling for communication with UEs **115**, or may operate under the control of a base station controller (not shown). In some examples, base stations **105** may be macro cells, small cells, hot spots, or the like. Base stations **105** may also be referred to as evolved NodeBs (eNBs) **105**.

A base station **105** may be connected by an S1 interface to the core network **130**. The core network may be an evolved packet core (EPC), which may include at least one mobility management entity (MME), at least one serving gateway (S-GW), and at least one Packet Data Network (PDN) gateway (P-GW). The MME may be the control node that processes the signaling between the UE **115** and the EPC. All user Internet Protocol (IP) packets may be transferred through the S-GW, which itself may be connected to the P-GW. The P-GW may provide IP address allocation as well as other functions. The P-GW may be connected to the network operators IP services. The operators IP services may include the Internet, the Intranet, an IP Multimedia Subsystem (IMS), and a Packet-Switched (PS) Streaming Service.

The core network **130** may provide user authentication, access authorization, tracking, Internet Protocol (IP) connectivity, and other access, routing, or mobility functions. At least some of the network devices, such as base station **105** may include subcomponents such as an access network entity, which may be an example of an access node controller (ANC). Each access network entity may communicate with a number of UEs **115** through a number of other access network transmission entities, each of which may be an example of a smart radio head, or a transmission/reception point (TRP). In some configurations, various functions of each access network entity or base station **105** may be distributed across various network devices (e.g., radio heads and access network controllers) or consolidated into a single network device (e.g., a base station **105**).

Wireless communications system **100** may operate in an ultra-high frequency (UHF) frequency region using frequency bands from 700 MHz to 2600 MHz (2.6 GHz), although some networks (e.g., a wireless local area network (WLAN)) may use frequencies as high as 4 GHz. This region may also be known as the decimeter band, since the wavelengths range from approximately one decimeter to one meter in length. UHF waves may propagate mainly by line of sight, and may be blocked by buildings and environmental features. However, the waves may penetrate walls sufficiently to provide service to UEs **115** located indoors. Transmission of UHF waves is characterized by smaller antennas and shorter range (e.g., less than 100 km) compared to transmission using the smaller frequencies (and longer waves) of the high frequency (HF) or very high frequency (VHF) portion of the spectrum. In some cases, wireless communications system **100** may also utilize extremely high frequency (EHF) portions of the spectrum (e.g., from 30 GHz to 300 GHz). This region may also be known as the millimeter band, since the wavelengths range from approximately one millimeter to one centimeter in length. Thus, EHF antennas may be even smaller and more closely spaced than UHF antennas. In some cases, this may facilitate use of antenna arrays within a UE **115** (e.g., for directional beamforming). However, EHF transmissions

may be subject to even greater atmospheric attenuation and shorter range than UHF transmissions.

Thus, wireless communications system **100** may support millimeter wave (mmW) communications between UEs **115** and base stations **105**. Devices operating in mmW or EHF bands may have multiple antennas to allow beamforming. That is, a base station **105** may use multiple antennas or antenna arrays to conduct beamforming operations for directional communications with a UE **115**. Beamforming (which may also be referred to as spatial filtering or directional transmission) is a signal processing technique that may be used at a transmitter (e.g., a base station **105**) to shape and/or steer an overall antenna beam in the direction of a target receiver (e.g., a UE **115**). This may be achieved by combining elements in an antenna array in such a way that transmitted signals at particular angles experience constructive interference while others experience destructive interference.

Multiple-input multiple-output (MIMO) wireless systems use a transmission scheme between a transmitter (e.g., a base station **105**) and a receiver (e.g., a UE **115**), where both transmitter and receiver are equipped with multiple antennas. Some portions of wireless communications system **100** may use beamforming. For example, base station **105** may have an antenna array with a number of rows and columns of antenna ports that the base station **105** may use for beamforming in its communication with UE **115**. Signals may be transmitted multiple times in different directions (e.g., each transmission may be beamformed differently). A mmW receiver (e.g., a UE **115**) may try multiple beams (e.g., antenna subarrays) while receiving the synchronization signals.

In some cases, the antennas of a base station **105** or UE **115** may be located within one or more antenna arrays, which may support beamforming or MIMO operation. One or more base station antennas or antenna arrays may be collocated at an antenna assembly, such as an antenna tower. In some cases, antennas or antenna arrays associated with a base station **105** may be located in diverse geographic locations. A base station **105** may multiple use antennas or antenna arrays to conduct beamforming operations for directional communications with a UE **115**.

In some cases, wireless communications system **100** may be a packet-based network that operate according to a layered protocol stack. In the user plane, communications at the bearer or Packet Data Convergence Protocol (PDCP) layer may be IP-based. A Radio Link Control (RLC) layer may in some cases perform packet segmentation and reassembly to communicate over logical channels. A Medium Access Control (MAC) layer may perform priority handling and multiplexing of logical channels into transport channels. The MAC layer may also use Hybrid ARQ (HARD) to provide retransmission at the MAC layer to improve link efficiency. In the control plane, the Radio Resource Control (RRC) protocol layer may provide establishment, configuration, and maintenance of an RRC connection between a UE **115** and a network device, base station **105**, or core network **130** supporting radio bearers for user plane data. At the Physical (PHY) layer, transport channels may be mapped to physical channels.

Time intervals in LTE or NR may be expressed in multiples of a basic time unit (which may be a sampling period of $T_s = 1/30{,}720{,}000$ seconds). Time resources may be organized according to radio frames of length of 10 ms ($T_f = 307200 T_s$), which may be identified by a system frame number (SFN) ranging from 0 to 1023. Each frame may include ten 1 ms subframes numbered from 0 to 9. A subframe may be further divided into two 0.5 ms slots, each of which contains 6 or 7 modulation symbol periods (depending on the length of the cyclic prefix prepended to each symbol). Excluding the cyclic prefix, each symbol contains 2048 sample periods. In some cases the subframe may be the smallest scheduling unit, also known as a TTI. In other cases, a TTI may be shorter than a subframe or may be dynamically selected (e.g., in short TTI bursts or in selected component carriers using short TTIs, for example, slots or mini-slots).

A resource element may include one symbol period and one subcarrier (e.g., a 15 KHz frequency range). A resource block may contain 12 consecutive subcarriers in the frequency domain and, for a normal cyclic prefix in each OFDM symbol, 7 consecutive OFDM symbols in the time domain (1 slot), or 84 resource elements. The number of bits carried by each resource element may depend on the modulation scheme (the configuration of symbols that may be selected during each symbol period). Thus, the more resource blocks that a UE receives and the higher the modulation scheme, the higher the data rate may be.

Wireless communications system **100** may support operation on multiple cells or carriers, a feature which may be referred to as carrier aggregation (CA) or multi-carrier operation. A carrier may also be referred to as a component carrier (CC), a layer, a channel, etc. The terms "carrier," "component carrier," "cell," and "channel" may be used interchangeably herein. A UE **115** may be configured with multiple downlink CCs and one or more uplink CCs for carrier aggregation. Carrier aggregation may be used with both FDD and TDD component carriers.

In some cases, wireless communications system **100** may utilize enhanced component carriers (eCCs). An eCC may be characterized by one or more features including: wider bandwidth, shorter symbol duration, shorter TTIs, and modified control channel configuration. In some cases, an eCC may be associated with a carrier aggregation configuration or a dual connectivity configuration (e.g., when multiple serving cells have a suboptimal or non-ideal backhaul link). An eCC may also be configured for use in unlicensed spectrum or shared spectrum (where more than one operator is allowed to use the spectrum). An eCC characterized by wide bandwidth may include one or more segments that may be utilized by UEs **115** that are not capable of monitoring the whole bandwidth or prefer to use a limited bandwidth (e.g., to conserve power).

In some cases, an eCC may utilize a different symbol duration than other CCs, which may include use of a reduced symbol duration as compared with symbol durations of the other CCs. A shorter symbol duration is associated with increased subcarrier spacing. A device, such as a UE **115** or base station **105**, utilizing eCCs may transmit wideband signals (e.g., 20, 40, 60, 80 MHz, etc.) at reduced symbol durations (e.g., 16.67 microseconds). A TTI in eCC may include one or multiple symbols. In some cases, the TTI duration (that is, the number of symbols in a TTI) may be variable.

A shared radio frequency spectrum band may be utilized in an NR shared spectrum system. For example, an NR shared spectrum may utilize any combination of licensed, shared, and unlicensed spectrums, among others. The flexibility of eCC symbol duration and subcarrier spacing may allow for the use of eCC across multiple spectrums. In some examples, NR shared spectrum may increase spectrum utilization and spectral efficiency, specifically through dynamic vertical (e.g., across frequency) and horizontal (e.g., across time) sharing of resources.

In some cases, wireless system **100** may utilize both licensed and unlicensed radio frequency spectrum bands. For example, wireless system **100** may employ LTE License Assisted Access (LTE-LAA) or LTE Unlicensed (LTE U) radio access technology or NR technology in an unlicensed band such as the 5 GHz Industrial, Scientific, and Medical (ISM) band. When operating in unlicensed radio frequency spectrum bands, wireless devices such as base stations **105** and UEs **115** may employ listen-before-talk (LBT) procedures to ensure the channel is clear before transmitting data. In some cases, operations in unlicensed bands may be based on a CA configuration in conjunction with CCs operating in a licensed band. Operations in unlicensed spectrum may include downlink transmissions, uplink transmissions, or both. Duplexing in unlicensed spectrum may be based on frequency division duplexing (FDD), time division duplexing (TDD) or a combination of both.

New radio (NR) systems provide for slot-aggregation in which a base station may grant a UE resources in one or more slots. Conventional NR systems lack techniques for handling slots having a special structure that fall within the set of aggregated slots. The described techniques provide for processing a grant of resources within a set of aggregated TTIs, and for reassignment of a TTI scheduled by a prior grant.

FIG. **2** illustrates an example diagram of a wireless communications system **200** that supports discontinuous scheduling in accordance with various aspects of the present disclosure. In some examples, wireless communications system **200** may implement aspects of wireless communication system **100**. Wireless communications system **200** may include a base station **105**-*a* and a UE **115**-*a*, which may be examples of the corresponding devices described with reference to FIG. **1**.

In some examples, base station **105**-*a* may communicate with one or more UEs **115** within geographic coverage area **205**. For example, base station **105**-*a* may be in communication with UE **115**-*a* via bidirectional communication link **210**. In some examples, time and frequency resources may include a bandwidth that is divided into transmission time intervals (TTIs) **215** in which the base station **105**-*a* and UE **115**-*a* may communicate. In some examples, a base station **105**-*a* may provide a grant of resources within a set of aggregated TTIs **220** to a UE **115**-*a*, and the base station **105**-*a* and the UE **115**-*a* may use the resources for communication of uplink and/or downlink data. The set of aggregated TTIs **220** may include an excluded TTI **215**-*a* that is not part of the grant of resources, and the base station **105**-*a* and the UE **115**-*a* may account for the excluded TTI **215**-*a* when communicating.

FIG. **3** illustrates an example diagram **300** of TTIs that supports discontinuous scheduling in accordance with various aspects of the present disclosure. As noted above, time and frequency resources may include a bandwidth that may be divided into TTIs **215**-*a* in which the base station **105**-*a* and UE **115**-*a* may communicate. The TTIs **215**-*a* may represent time durations that may be of a fixed length within the bandwidth. A TTI may include a control channel **305** and a shared data channel **310**. The control channel **305** may be a portion of the TTI **215**-*a* for transporting control information between the base station **105**-*a* and at least the UE **115**-*a*. Downlink control information (DCI) and group-common DCI are examples of control information. DCI may include control information for a particular UE, and group-common DCI may include control information for a group of UEs. The data channel **310** may be a shared data channel for transporting uplink data, downlink data, or both, and the base station **105**-*a* may allocate resources of the data channel **310** to one or more UEs **115** for communication of the uplink data, downlink data, or both.

In some examples, a TTI may be further divided into two or more shortened TTIs (sTTIs). In the depicted example, TTI**5** includes three sTTIs **315**-*a*, **315**-*b*, and **315**-*c*. Each sTTI may be of the same duration, or at least one sTTI may have different duration than at least one other sTTI. Each sTTI **315** may include a control channel **305**-*a* and a data channel **310**-*a*. The control channel **305**-*a* may be similar to the control channel **305**, and the data channel **310**-*a* may be similar to data channel **310** but of a shorter duration. For example, the data channel **310**-*a* may include fewer OFDM symbol periods than data channel **310**.

In some examples, the base station **105**-*a* may provide a grant of resources within a set of aggregated TTIs **220** to be used for communication of uplink data, downlink data, or both. FIG. **4** illustrates an example diagram **400** of a set of aggregated TTIs that supports discontinuous scheduling in accordance with various aspects of the present disclosure. At some time, a base station **105**-*a* may determine to provide a UE with a grant of resources within a set of aggregated TTIs **220**-*a*. In the depicted timeline **425**, the base station **105**-*a* may include a grant **405** in a control channel at TTI **215**-*b* for providing UE **115**-*a* a grant of resources within a set of aggregated TTIs **220**-*a*. The allocated resources may include at least a portion of a bandwidth and one or more symbol periods of a data channel within each TTI of the set of aggregated TTIs **220**-*a*. In some examples, the set of aggregated TTIs **220**-*a* may be contiguous to one another in time and/or frequency. In other examples, two or more TTIs in the set of aggregated TTIs **220**-*a* may be non-contiguous to one another in time and/or frequency. Two or more non-contiguous TTIs may be separated in time, frequency, or both.

In the depicted example, grant **405** indicates that UE **115**-*a* is being granted resources in a set of aggregated TTIs **220**-*a*, beginning at TTI**0**, and continuing through TTI**5**. A time duration **410** occurs between an end of the grant **405** and the beginning TTI**0**.

The grant **405** may be a multi-slot grant indication for identifying in which TTIs resources are being allocated to the UE **115**-*a*. In an example, the grant **405** may be a bitmap that includes a sequence of bits indicating in which TTIs, or sTTIs in one or more TTIs, resources are being allocated to the UE **115**-*a*. A bit in the sequence having a first value may indicate that resources are allocated in that TTI for the UE **115**-*a*, and the bit having a second value may indicate that resources are not allocated in that TTI for the UE **115**-*a*. With reference to FIG. **4**, the bit sequence may indicate that the next four TTIs do not have resources allocated in that TTI for the UE **115**-*a*, but the following six TTIs (e.g., TTI**0** to TTI**5**) do have resources allocated in that TTI for the UE **115**-*a*. In this example, the bit sequence in the bit map may be as follows [0, 0, 0, 0, 1, 1, 1, 1, 1, 1]. The bitmap is flexible to support contiguous and non-contiguous TTI aggregation.

In some examples, to reduce overhead, the bitmap may be an index into a set of possible TTI assignments. The base station **105**-*a* may preconfigure with the UE **115**-*a* with a set of possible TTI assignments, and the grant **405** may include an index to identify which configuration of the set of possible TTI configurations is being allocated to the UE **115**-*a*. For example, a first index value in the set of possible TTI configurations may correspond to the following bit map sequence [0, 0, 0, 0, 1, 1, 1, 1, 1, 1], a second index value may correspond to the following bit map sequence [0, 0, 0, 0, 1, 0, 1, 1, 1, 1, 1], a third index value may correspond to

the following bit map sequence [0, 0, 0, 0, 1, 0, 0, 1, 1, 1, 1, 1], and a fourth index value may correspond to the following bit map sequence [0, 0, 0, 0, 1, 0, 0, 1, 0, 1, 1, 1, 1]. In this example, the index value may be a 2-bit sequence for distinguishing between the four different index values (e.g., 00 for first index, 01 for second index, 10 for third index, and 11 for fourth index). These techniques may be applied to create an index into a set of any number of possible TTI configurations. In further examples, the configurations may include TTIs of identical time durations, TTIs of different time durations, or the like.

In some examples, some TTIs, or sTTIs, within a set of TTIs specified in the grant **405** may be implicitly or explicitly excluded. In an example, certain TTIs and/or sTTIs may transport data at periodic or at known intervals to facilitate communication between the base station **105**-*a* and the UE **115**-*a*. A TTI for a random access channel for uplink and a TTI for synchronization for downlink are two such examples. In some examples, a TTI may be excluded because one or more of the symbols to be communicated in the TTI is configured for an opposite link direction than at least one of the other TTIs in the plurality of aggregated TTIs. For example, one or more of the symbols in the excluded TTI may be indicated (e.g., via configuration information received by the UE **115**-*a*) as a downlink symbol (for an uplink grant) or as an uplink symbol (for a downlink grant). Other examples include sTTIs carrying channel state information reference signals (CSIRS) on the downlink, sounding reference signals (SRS) on the uplink, a short-UL-control block on the uplink, or the like. Further examples include TTIs reserved for forward compatibility. In some examples, the base station **105**-*a* may semi-statically configure which TTIs and sTTIs are to be excluded. The base station **105**-*a* may indicate and/or update the configuration in a master information block, a minimum system information block (mSIB), an other SIB (OSIB), radio resource control (RRC) messaging, group-common DCI signaling, or the like.

The periodic or known intervals of such excluded TTIs may be preconfigured and the UE **115**-*a* may know to exclude such TTIs from TTIs in a grant **405**. In other examples, the grant **405** may provide an explicit indication that excludes such TTIs from the grant of resources. A TTI that is to be excluded from the grant of resources is referred to herein as an excluded TTI, and a sTTI within a TTI that is to be excluded from the grant of resources is referred to herein as an excluded sTTI. In FIG. **4**, TTI**3** is shaded and is an example of an excluded TTI.

In some examples, the grant **405** may include a starting TTI indication and an ending TTI indication and/or a TTI number indication. The starting TTI indication may identify a first TTI that includes a grant of resources for the UE **115**-*a*. In FIG. **4**, the starting TTI indication may identify TTI**0**. The ending TTI indication may identify a last TTI that includes a grant of resources for the UE **115**-*a*. In FIG. **4**, the ending TTI indication may identify TTI**5**. The TTI number indicator may include the total number of TTIs in which resources are granted to the UE **115**-*a*. In FIG. **4**, the TTI number indicators may specify that 6 TTIs (e.g., TTI**0** to TTI**5**) grant resources to the UE **115**-*a*. The starting TTI indication may be a relative indicator that identifies a number of TTIs between the TTI including grant **405** and the beginning TTI (e.g., TTI**0**). The starting TTI indication may be a relative indicator that identifies a number of TTIs between the TTI including grant **405** and the ending TTI (e.g., TTI**5**).

In some examples, the ending TTI indication and/or the TTI number indication may or might not account for one or more excluded TTIs and/or one or more excluded sTTIs that are within the set of aggregated TTIs **220**-*a*. In an example, the UE **115**-*a* may determine that the grant **405** includes an excluded TTI within the set of aggregated TTIs **220**-*a*, and adjust the ending TTI indication to include an additional TTI for each excluded TTI within the set of aggregated TTIs **220**-*a*. In FIG. **4**, for example, the ending TTI indication may identify TTI**4**. The UE **115**-*a* may determine that TTI**3** is an excluded TTI, and adjust the ending TTI indication to be TTI**5**. In another example, the TTI number indication may indicate five TTIs. The UE **115**-*a* may determine that TTI**3** is an excluded TTI, and adjust the TTI number to be six TTIs. In some cases, the UE-**115**-*a* may communicate using fewer TTIs than the number of TTIs indicated by the starting TTI, the ending TTI, and/or the TTI number; e.g., by excluding the excluded TTI without adjusting the ending TTI indication or the TTI number indication.

The UE **115**-*a* may have the option to similarly adjust the ending TTI and/or the TTI number indicator when a TTI within the set of aggregated TTIs **220**-*a* includes one or more excluded sTTIs. In some examples, the UE **115**-*a* may maintain a TTI count of communicated TTIs of a set of aggregated TTIs based on determining whether to include one or more excluded TTIs in the TTI count. In some examples, the UE **115**-*a* may count the number of TTIs, and include in the count any TTIs having at least one excluded sTTI, but not include in the count any excluded TTI. In some examples, the UE **115**-*a* may include one or more excluded TTIs in the TTI count. In some examples, not including an excluded TTI in a count may provide the benefit that a longer time-span for a set of aggregated TTIs may be specified for the same grant overhead (e.g., DCI overhead).

In some examples, a TTI may be reassigned after transmission of grant **405**. FIG. **5** illustrates an example diagram **500** of TTI reassignment with rate-matching that supports discontinuous scheduling in accordance with various aspects of the present disclosure. The base station **105**-*a* may have the option to send a TTI reassignment indication **510** after sending the grant **405**. The TTI reassignment indication **510** may reassign resources of one or more TTIs in the set of aggregated TTIs identified in the grant **405**. Timeline **425** corresponds to a set of aggregated TTIs determined based on an initial grant **405**, similar to the timeline **425** shown in FIG. **4**, and timeline **505**-*a* corresponds to a set of aggregated TTIs determined based on a TTI reassignment indication **510** that reassigns a TTI within the initial grant **405**. A TTI may be reassigned, for example, to transport higher priority data. Examples of higher priority data may include URLLC data, a TTI reconfigured for forward compatibility, or the like. Higher priority data may preempt other transmissions (e.g., pre-empt regular enhanced mobile broadband (eMBB) transmissions). The TTI reassignment indication **510** may be part of DCI, group-common DCI, or the like. In other examples, the base station **105**-*a* may transmit the TTI reassignment indication **510** using radio resource control (RRC) signaling.

If the UE **115**-*a* has enough time to process the TTI reassignment indication **510** before a beginning TTI of the assigned set of aggregated TTIs **220**-*a*, the UE **115**-*a* may treat the TTI reassignment indication **510** as if it was provided along with the grant **405**. Timeline **425** may represent how communication would have occurred in the set of aggregated TTIs **220**-*a* corresponding to initial grant **405**. Timeline **505**-*a* includes the TTI reassignment indication **510** transmitted after grant **405**. In timeline **505**-*a*, the

TTI reassignment indication **510** indicates that TTI**1** is being reassigned, and hence TTI**1** is an excluded slot.

The base station **105**-*a* may process one or more capabilities of the UE **115**-*a* for determining whether the UE **115**-*a* has enough time to process the TTI reassignment indication **510**. When a connection is initially set up, or at other times, the base station **105**-*a* may query the UE **115**-*a* for one or more capabilities. At some time, the base station **105**-*a* may desire to reassign resources of a TTI that it previously granted to the UE **115**-*a* in an initial grant **405**. The base station **105**-*a* may determine one or more response time thresholds for the UE. A response time threshold may be an amount of time for the UE **115**-*s* to process and respond based on the one or more capabilities of the UE **115**-*a*. A first response time threshold may correspond to the amount of time between when the UE **115**-*a* receives data within resources of a TTI, decodes and processes the data, and transmits an acknowledgment message to indicate whether the decoded data passed error detection. For example, a k1 value is a minimum amount of time between when UE **115**-*a* receives and decodes a physical downlink shared channel (PDSCH), and transmits an acknowledgment message on the uplink indicating whether PDSCH data passed error detection. In this example, the first response time threshold may be set at the k1 value. In some examples, the base station **105**-*a* may measure how long after data is sent in a shared data channel for the UE to reply with an acknowledgment message, and may set the first response time threshold using the measured actual timing. In some examples, the measured actual timing may be a statistical value (e.g., average), a worst case value, or the like.

In FIG. **5**, for example, the base station **105**-*a* may determine a duration of time interval **515**-*a*. Time interval **515**-*a* may be the amount of time between when TTI reassignment indication **510** is transmitted and when the UE **115**-*a* is scheduled to send an acknowledgment message **520**. The base station **105**-*a* may compare the duration of time interval **515**-*a* to the first time threshold, and may transmit the TTI reassignment indication **510** if the duration of time interval **515**-*a* is greater than or equal to the first response time threshold.

A second response time threshold may correspond to the amount of time between when the UE **115**-*a* receives a grant, decodes and processes the grant, and can receive data within resources of a TTI specified in the grant. For example, a k2 value is a minimum amount of time between when UE **115**-*a* receives and decodes a grant within a physical downlink control channel (PDCCH), and transmits uplink data in a physical uplink shared channel (PUSCH) using resources specified in the grant. The second response time threshold may be set at the k2 value. In some examples, the base station **105**-*a* may measure how long after a grant is sent in a control channel the UE is capable of transmitting using resources in a TTI specified in the grant, and may set the second response time threshold using the measured actual timing. In some examples, the measured actual timing may be a statistical value (e.g., average), a worst case value, or the like. In some examples, the measured actual timing may be a function of positive acknowledgements and negative acknowledgements, where the threshold corresponds to when a rate positive acknowledgements satisfies a minimum positive acknowledgement rate (e.g., timing at which at least 99% of acknowledgments are positive acknowledgements). A response time threshold may be set based on other capabilities of the UE, or any combination of UE capabilities.

In FIG. **5**, for example, the base station **105**-*a* may determine an amount of time in time interval **515**-*b*. Time interval **515**-*b* may be the amount of time between when TTI reassignment indication **510** is transmitted and a beginning TTI of the set of aggregated TTIs **220**-*b*. The base station **105**-*a* may compare the duration of time interval **515**-*b* to the second response time threshold, and may transmit the TTI reassignment indication **510** if the duration of time interval **515**-*b* is greater than or equal to the second time threshold.

In some instances, the base station **105**-*a* may transmit the TTI reassignment indication **510** even if one or more response thresholds are not satisfied. In such a scenario, the UE **115**-*a* may determine that it does not have sufficient time to process the TTI reassignment indication **510**. If there is insufficient time, the UE **115**-*a* may ignore the TTI reassignment indication **510**. For example, the UE **115**-*a* may treat the TTI reassignment indication **510** as falsely passing error detection (e.g., false CRC pass on PDCCH) and ignore the TTI reassignment indication **510**. When the reassigned, and now excluded, TTI is received and decoded, the UE **115**-*a* may determine that data in the resources within the reassigned TTI (e.g., TTI**3**) differ from what the UE **115**-*a* expected (e.g., the data fails an error detection procedure, cyclic redundancy check (CRC), or the like), and may transmit a negative acknowledgement asking the base station **105**-*a* to retransmit.

In some examples, the UE **115**-*a* may be able to partially process the TTI reassignment indication **510**. Partial processing may impact computation of a transport block size. In some examples, the base station **105**-*a*, in the downlink, may be transmitting at least a portion of a transport block within the resources of the set of aggregated TTIs **220** specified in the grant **405**. Computation of a transport block size (TBS) typically accounts for an excluded TTI (e.g., TTI**3** in the example of FIG. **5**). In some circumstances, the TTI reassignment indication **510** indicating the excluded TTI occurs after the TBS has been computed and after transmission of some portion of the transport block has already begun. The base station **105**-*a* may thus not update the computation of the TBS size, and the UE **115**-*a* may determine that the excluded TTI or excluded sTTI has been punctured without re-computing the TBS. For example, the UE **115**-*a* may perform discontinuous transmission (DTX) of the excluded TTI without re-computing the TBS. For the uplink, the UE **115**-*a* may not re-compute the TBS size in a similar manner with the roles of the base station and UE being reversed in the prior example.

In some examples, the UE **115**-*a* may have sufficient time to receive and process the TTI reassignment indication **510**, and may transmit an acknowledgement message **520** indicating that the TTI reassignment indication **510** passed error detection prior to a beginning TTI of the adjusted set of aggregated TTIs **220**-*b* (e.g., before TTI). The acknowledgement message **520** may be, for example, a dedicated acknowledgement of DCI or PDCCH. In another example, the acknowledgement message **520** may be for a scheduled PDSCH or PUSCH transmission. In a further example, the acknowledgement message **520** may be an acknowledgement for a group-common-DCI.

In some cases, the UE **115**-*a* may update the set of aggregated TTIs **220**-*a* based on the TTI reassignment indication **510**. In some examples, the UE **115**-*a* may perform rate-matching to update the set of aggregated TTIs **220**-*a* based on the TTI reassignment indication **510**. Rate-matching may involve shifting a subset of the set of aggregated TTIs **220**-*a* by at least one TTI to determine an

adjusted set of aggregated TTIs **220**-*b*. In FIG. **5**, for example, TTI reassignment indication **510** indicates that TTI**3** is being excluded. In response, the UE **115**-*a* may shift each the subset of the set of aggregated TTIs **220**-*a* back by one TTI. Thus, the data the UE **115**-*a* initially expected to be received in the resources of TTI**3**, the UE **115**-*a* now expects to receive in the resources of TTI**4**. The data the UE **115**-*a* initially expected to be received in the resources of TTI**4**, the UE **115**-*a* now expects to receive in the resources of TTI**5**, and so forth. In this example, the UE **115**-*a* determines, from the grant **405** and TTI reassignment indication **510**, that the adjusted set of aggregated TTIs has been extended by one TTI. In some examples, the base station **105**-*a* may preconfigure the UE **115**-*a* with adjustment instructions specifying how the UE **115**-*a* is to adjust the set of aggregated TTIs when a TTI reassignment indication **510** is received. For example, the base station **105**-*a* may transmit the adjustment instructions in, for example, radio resource control (RRC) signaling. In other examples, the TTI reassignment indication **510** may include the adjustment instructions in a DCI, a group-common DCI, or the like. In some examples, the base station **105**-*a* may generate the adjustment instructions based on one or more capabilities of the UE **115**-*a*, measurements of actual response timings, or the like.

When a TTI reassignment indication **510** is sent after the grant **405** to identify one or more excluded TTIs, the base station **105**-*a* may adjust the measured actual response timings to account for the one or more excluded TTIs. For example, if the UE **115**-*a* extends the grant **405** to include an additional TTI because of the TTI reassignment indication **510**, the base station **105**-*a* may adjust the measured actual response timings to account for the additional TTI for setting and/or updating a response timing threshold.

In some instances, a TTI identified by the TTI reassignment indication **510** may be punctured. FIG. **6** illustrates an example diagram **600** of TTI reassignment with puncturing that supports discontinuous scheduling in accordance with various aspects of the present disclosure. Puncturing may involve discarding bits previously scheduled to be transmitted within resources of a TTI. FIG. **6** depicts timeline **425**, as previously described in FIGS. **4**-**5**, without data puncturing, timeline **605**-*a* that depicts sTTI puncturing, and timeline **605**-*b* that depicts TTI puncturing. As described above, in timeline **425**, a grant **405** of resources is associated with a set of aggregated TTIs **220**-*a*. In timeline **605**-*a*, the base station **105**-*a* may determine to transmit a TTI reassignment indication **510**, and the determination may be based on timing intervals **515**-*a*, **515**-*b*, as described in FIG. **5**. The UE **115**-*a* may also transmit an acknowledgment **520** in response to the TTI reassignment indication **510**. In timeline **605**-*a*, one or more sTTIs in TTI**1** may be punctured, as represented by the shading at **625**-*a*. The resources of the one or more punctured sTTIs, which may include at least some of the bandwidth, may be used to communicate different data than the data scheduled by the grant **405**. In the downlink, the base station **105**-*a* may transmit the different data to the UE **115**-*a* or a different UE within the resources corresponding to the punctured one or more sTTIs. In the uplink, the UE **115**-*a* may transmit the different data to the base station **105**-*a* or other device within the resources corresponding to the punctured one or more sTTIs. Timeline **605**-*b* is similar to timeline **605**-*a*, but up to all of the resources of TTI**3** are punctured as represented by the shading at **625**-*b*.

In some examples, beamforming may be used to beamform data on multiple beams within an excluded TTI. FIG. **7** illustrates an example diagram **700** of a set of aggregated TTIs communicated using multiple beams that supports discontinuous scheduling in accordance with various aspects of the present disclosure. Depicted is timeline **425** previously described in FIG. **4**, and resources **720** of the excluded TTI (e.g., TTI**3**) are shown. In the depicted example, the resources **720** may correspond to a set of sub-carriers that collectively span a bandwidth and a set of symbol periods that collectively span the TTI. Beamforming techniques may be used to transmit symbols on sub-carriers using one or more transmission beams, and a receiver may select one or more receive beams to receive symbols transmitted using the one or more transmission beams. In the depicted example, transmission (TX) beam X may be used to transmit symbols within a first two columns of resources **720**, and TX beam Y may be used to transmit symbols within the remaining columns of resources **720**.

In an example, an excluded TTI may be a synchronization TTI in which synchronization signals are communicated for maintaining synchronization between the base station **105**-*a* and the UE **115**-*a*. The synchronization TTI may include synchronization symbols that use a different TX beam than one or more transmission beams used to transmit symbols carrying other types of data (e.g., a different beam is used to transmit PDSCH data). The base station **105**-*a* may frequency division multiplex (FDM) synchronization symbols and data symbols on a first TX beam within the synchronization TTI, and may transmit data symbols on a second, different TX beam within the synchronization TTI. The UE **115**-*a* may perform a synchronization procedure with the base station **105**-*a* to determine a beam direction for a first receive beam to receive the synchronization symbols and the data symbols frequency division multiplexed on the first TX beam, and a second first receive beam to receive the data symbols on the second TX beam.

In the depicted example, the base station **105**-*a* may frequency division multiplex data and synchronization data onto symbols for transmission on TX Beam X using the first two symbol periods of the resources **720**. In the depicted example, the top six sub-carriers of resources **720** on TX Beam X transport data (represented using a first type of shading), and the bottom four sub-carriers of resources **720** on TX Beam X transport synchronization data (represented using a second type of shading). Other sub-carrier configurations for frequency division multiplexing data and synchronization data onto symbols for transmission on TX Beam X may also be used. The base station **105**-*a* may frequency division multiplex data onto symbols for transmission on TX Beam Y using the remaining symbol periods of the resources **720**. The unshaded portion of the resources **720** may be used to transmit other data on TX Beam Y. In the depicted example, receive (RX) beam A may be used to receive symbols transmitted on TX Beam X, and RX beam B may be used to receive symbols transmitted on TX Beam Y.

These beamforming techniques may be applied in other scenarios. For example, for a RACH TTI, a UE **115**-*a* may similarly frequency division multiplex RACH data and other uplink data onto a same transmission beam. In another example, the base station **105**-*a*, the UE **115**-*a*, or either, may frequency division multiplex symbols onto a beam in one or more TTIs reserved for forward-compatibility. Moreover, these beamforming techniques described herein may be applied for both control and data transmissions.

In some examples, the TTI reassignment indication **510** may result in the UE **115**-*a* being scheduled to transmit acknowledgment data and channel state information (CSI) in

a same TTI. To conserve resources, the UE **115**-*a* may determine to merge the acknowledgment data and the CSI.

FIG. **8** illustrates an example diagram **800** of merging channel state information and acknowledgment data that supports discontinuous scheduling in accordance with various aspects of the present disclosure. Timeline **805**-*a* corresponds to a set of aggregated TTIs **220**-*d* in an initial grant **405**, and timeline **805**-*b* corresponds to a set of aggregated TTIs **220**-*e* after updating the initial grant **405** based on a TTI reassignment indication **510**. The set of aggregated TTIs **220**-*d* includes TTI**0** to TTI**3**. and the adjusted set of aggregated TTIs **220**-*e* includes TTI**0** to TTI**4**, with TTI**3** being changed to an excluded TTI. The UE **115**-*a* is scheduled to transmit an acknowledgment message **810** a defined number of TTIs after an ending TTI in the set of aggregated TTIs **220**. The acknowledgment message **810** may indicate whether data received in the resources of the set of aggregated TTIs **220**-*d* passed error detection. In the example depicted in timeline **805**-*a*, the UE **115**-*a* is scheduled to transmit acknowledgment message **810** in the 4th TTI after the ending TTI (e.g., in TTI**7**). The UE **115**-*a* may also be scheduled to send CSI **815** to be base station **105**-*a* at periodic time intervals or at predefined times. The CSI **815** may include information about a communication channel used by the base station **105**-*a* and the UE **115**-*a*. Examples of CSI include one or more of a Channel Quality Indicator (CQI), a precoding matrix indicator (PMI), a precoding type indicator (PTI), a rank indication (RI), or the like. In the example depicted in timeline **805**-*a*, the UE **115**-*a* may be scheduled to transmit CSI **815** in TTI**8**.

Because of a TTI reassignment indication **510**, the UE **115**-*a* may adjust the set of aggregated TTIs **220** from the set of aggregated TTIs **220**-*d* shown in timeline **805**-*a* to the set of aggregated TTIs **220**-*e* shown in timeline **805**-*b*. The adjustment may move back the location of where the acknowledgment message **810** is scheduled to be transmitted, and the adjusted location may overlap with the TTI in which CSI **815** is scheduled to be transmitted. In the example depicted in timeline **805**-*b*, the acknowledgment message **810** and CSI **815** are both scheduled to be transmitted in TTI**8**. Rather than separately sending the acknowledgment message **810** and CSI **815** in the same TTI, the UE **115**-*a* may merge the acknowledgment message **810** and CSI **815**. For example, the UE **115**-*a* may add an acknowledgment bit to the CSI **815**. The acknowledgment bit may be set to a first value if the data received in the resources of the set of aggregated TTIs **220**-*e* passed error detection (e.g., bit set to 1), and set to a second value if the data received in the resources of the set of aggregated TTIs **220**-*e* did not pass error detection (e.g., bit set to 0). The UE **115**-*a* may transmit a merged feedback message **820** that includes the CSI **815** with the added acknowledgment bit.

In some examples, an acknowledgment message may be transported over multiple TTIs, and the techniques described herein may be used for merging a multi-TTI acknowledgment with CSI. FIG. **9** illustrates an example diagram **900** of merging channel state information and acknowledgment data that supports discontinuous scheduling in accordance with various aspects of the present disclosure. Timeline **905**-*a* corresponds to a set of aggregated TTIs **220**-*f* in an initial grant **405**, and timeline **905**-*b* corresponds to a set of aggregated TTIs **220**-*g* after updating the initial grant **405** based on a TTI reassignment indication **510**. The set of aggregated TTIs **220**-*f* includes TTI**0** to TTI**3**. and the adjusted set of aggregated TTIs **220**-*g* includes TTI**0** to TTI**4**, with TTI**2** and TTI**3** each being changed to an excluded TTI. The UE **115**-*a* is initially scheduled to transmit a multi-TTI acknowledgment message **910** for acknowledging whether data received in one or more TTIs of the set of aggregated TTIs **220** passed error detection. In the depicted example in timeline **905**-*a*, the multi-TTI acknowledgment message **910** includes three acknowledgment transmissions **910**-*a*, **910**-*b*, and **910**-*c* that are scheduled to be transmitted in TTI**7**, TTI**8**, and TTI**9**, respectively. The acknowledgment transmissions **910**-*a*, **910**-*b*, and **910**-*c* may be repetitions of the same transmission, or may include a joint encoding and transmission of the single acknowledgment message **910** over three TTIs. The UE **115**-*a* may also be scheduled to send CSI **915** to be base station **105**-*a* at periodic time intervals or at predefined times. In the example depicted in timeline **905**-*a*, the UE **115**-*a* may be scheduled to transmit CSI **915** in TTI**10**.

Because of a TTI reassignment indication **510**, the UE **115**-*a* may adjust the set of aggregated TTIs **220** from the set of aggregated TTIs **220**-*f* shown in timeline **905**-*a* to the set of aggregated TTIs **220**-*g* shown in timeline **905**-*b*. The adjustment may move back the location of where the acknowledgment transmissions **910**-*a*, **910**-*b*, and **910**-*c* are scheduled to be transmitted, and one of the acknowledgment transmissions **910**-*a*, **910**-*b*, and **910**-*c* may overlap with the TTI in which CSI **915** is scheduled to be transmitted. In the example depicted in timeline **905**-*b*, the acknowledgment transmissions **910**-*a*, **910**-*b*, and **910**-*c* are each shifted back by two TTIs such that acknowledgment transmission **910**-*b* overlaps with CSI **915** in TTI**10**. If the UE has already started transmission of the multi-TTI acknowledgment message **910** (e.g., already transmitted acknowledgment transmission **910**-*a*), the UE **115**-*a* may cancel the remainder of the multi-TTI acknowledgment message **910** and merge the remaining acknowledgment transmissions (e.g., **910**-*b*, **910**-*c*) with the CSI **915**. Similar to the description above, the UE **115**-*a* may add an acknowledgment bit to the CSI **915**. In the depicted example, the UE **115**-*a* may add an acknowledgment bit for each of the acknowledgment transmissions **910**-*b*, **910**-*c* to the CSI **915** to form a merged feedback message **920**, and may transmit the merged feedback message **920** in TTI**10** that includes two additional acknowledgment bits.

The UE **115**-*a* may merge a multi-TTI acknowledgment message with a CSI in other manners. FIG. **10** illustrates an example diagram **1000** of merging channel state information and acknowledgment data that supports discontinuous scheduling in accordance with various aspects of the present disclosure. Timeline **905**-*a*, is the same timeline as shown in FIG. **9**, corresponds to a set of aggregated TTIs **220**-*f* in an initial grant **405**. Timelines **1005**-*a* and **1005**-*b* correspond to a set of aggregated TTIs **220**-*g* after updating the initial grant **405** based on a TTI reassignment indication **510**. The set of aggregated TTIs **220**-*f* includes TTI**0** to TTI**3**, and the adjusted set of aggregated TTIs **220**-*g* includes TTI**0** to TTI**4**, with TTI**2** and TTI**3** each being changed to an excluded TTI. The UE **115**-*a* is scheduled to transmit a multi-TTI acknowledgment message **910** for acknowledging whether data received in one or more TTIs of the set of aggregated TTIs **220** passed error detection. In the depicted example of timeline **905**-*a*, the multi-TTI acknowledgment message **910** includes three acknowledgment transmissions **910**-*a*, **910**-*b*, and **910**-*c* that are scheduled to be transmitted in TTI**7**, TTI**8**, and TTI**9**, respectively. The UE **115**-*a* may also be scheduled to send CSI **915** to be base station **105**-*a* at periodic time intervals or at predefined times. In the example depicted in timeline **905**-*a*, the UE **115**-*a* may be scheduled to transmit CSI **915** in TTI**10**.

Because of a TTI reassignment indication **510**, the UE **115**-*a* may adjust the set of aggregated TTIs **220** from the set of aggregated TTIs **220**-*f* shown in timeline **905**-*a* to the set of aggregated TTIs **220**-*g* shown in timelines **1005**-*a* and **1005**-*b*. The adjustment may move back the location of where the acknowledgment transmissions **910**-*a*, **910**-*b*, and **910**-*c* are scheduled to be transmitted, and one of the acknowledgment transmissions **910**-*a*, **910**-*b*, and **910**-*c* may overlap with the TTI in which CSI **915** is scheduled to be transmitted. In the example depicted in timeline **1005**-*a*, the acknowledgment transmissions **910**-*a*, **910**-*b*, and **910**-*c* are each shifted back by two TTIs such that acknowledgment transmission **910**-*b* overlaps with CSI **915** in TTI**10** in timelines **1005**-*a* and **1005**-*b*. In timeline **1005**-*a*, the UE **115**-*a* may transmit both acknowledgment transmission **910**-*b* and CSI **915** in the same TTI. The UE **115**-*a* may use, for example, frequency division multiplexing, spatial division multiplexing, or the like to transmit both the acknowledgment transmission **910**-*b* and CSI **915** in the same TTI (e.g., transmit both in TTI**10**).

In timeline **1005**-*b*, the UE **115**-*a* may transmit the non-overlapping acknowledgment transmissions **910**-*a* and **910**-*c* in the updated locations (e.g., respectively in TTI**9** and TTI**11**), and generate a feedback message **1020**. In some examples, the UE **115**-*a* may DTX transmission of the acknowledgment transmission **910**-*b* in the overlapping TTI and instead transmit the CSI **915**, but not the acknowledgment transmission **910**-*b*, as the feedback message **1020**. In other examples, the feedback message **1020** may be a merged feedback message by merging acknowledgment transmission **910**-*b* and CSI **915**, similar to the discussion of the feedback message **820** provided above in FIG. **8**. The techniques described herein for merging an acknowledgment into subsequent CSI are examples, and these techniques may apply to other combinations of uplink control information. For example, CSI could be merged into an acknowledgment, two different types of CSI could be merged (e.g., merge periodic and aperiodic CSI), or the like.

Advantageously, the examples described herein may enable a wireless communication system as described herein to reassign a TTI that was previously assigned in a grant. A determination of whether to reassign a TTI may consider capabilities of a UE to process a TTI reassignment indication prior to a beginning of a set of aggregated TTIs associated with the grant. Moreover, resources may be conserved by merging of acknowledgment data and CSI to account for a change in which TTI an acknowledgment message is scheduled to be transmitted.

FIG. **11** shows a block diagram **1100** of a wireless device **1105** that supports discontinuous scheduling in accordance with aspects of the present disclosure. Wireless device **1105** may be an example of aspects of a user equipment (UE) **115** as described herein. Wireless device **1105** may include receiver **1110**, UE communications manager **1115**, and transmitter **1120**. Wireless device **1105** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

Receiver **1110** may receive information such as packets, user data, or control information associated with various information channels (e.g., control channels, data channels, and information related to discontinuous scheduling, etc.). Information may be passed on to other components of the device. The receiver **1110** may be communicatively coupled, and pass information, to the UE Communications manager via link **1150**. The receiver **1110** may be an example of aspects of the transceiver **1435** described with reference to FIG. **14**. The receiver **1110** may utilize a single antenna or a set of antennas.

UE communications manager **1115** may be an example of aspects of the UE communications manager **1415** described with reference to FIG. **14**.

UE communications manager **1115** and/or at least some of its various sub-components may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions of the UE communications manager **1115** and/or at least some of its various sub-components may be executed by a general-purpose processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), an field-programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described in the present disclosure. The UE communications manager **1115** and/or at least some of its various sub-components may be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations by one or more physical devices. In some examples, UE communications manager **1115** and/or at least some of its various sub-components may be a separate and distinct component in accordance with various aspects of the present disclosure. In other examples, UE communications manager **1115** and/or at least some of its various sub-components may be combined with one or more other hardware components, including but not limited to an I/O component, a transceiver, a network server, another computing device, one or more other components described in the present disclosure, or a combination thereof in accordance with various aspects of the present disclosure.

UE communications manager **1115** may monitor a control channel for a grant of resources of a communication channel over a set of aggregated transmission time intervals (TTIs), identify a location of an excluded TTI within the set of aggregated TTIs, and communicate via the resources of the communication channel over at least a subset of the set of aggregated TTIs based on the grant and the identified location of the excluded TTI. The UE communications manager **1115** may be communicatively coupled, and pass information, to the transmitter **1120**.

Transmitter **1120** may transmit signals generated by other components of the device. In some examples, the transmitter **1120** may be collocated with a receiver **1110** in a transceiver module. For example, the transmitter **1120** may be an example of aspects of the transceiver **1435** described with reference to FIG. **14**. The transmitter **1120** may be communicatively coupled with, and receive information from, the UE Communications manager via link **1155**. The transmitter **1120** may utilize a single antenna or a set of antennas.

FIG. **12** shows a block diagram **1200** of a wireless device **1205** that supports discontinuous scheduling in accordance with aspects of the present disclosure. Wireless device **1205** may be an example of aspects of a wireless device **1105** or a UE **115** as described with reference to FIG. **11**. Wireless device **1205** may include receiver **1210**, UE communications manager **1215**, and transmitter **1220**. Wireless device **1205** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

Receiver **1210** may receive information such as packets, user data, or control information associated with various information channels (e.g., control channels, data channels, and information related to discontinuous scheduling, etc.).

Information may be passed on to other components of the device. The receiver **1210** may be an example of aspects of the transceiver **1435** described with reference to FIG. **14**. The receiver **1210** may utilize a single antenna or a set of antennas.

UE communications manager **1215** may be an example of aspects of the UE communications manager **1415** described with reference to FIG. **14**.

UE communications manager **1215** may also include monitor component **1225**, location identifier **1230**, and resource utilizer **1235**.

Monitor component **1225** may monitor a control channel for a grant of resources of a communication channel over a set of aggregated transmission time intervals (TTIs). In some cases, the grant includes a bit sequence identifying the set of aggregated TTIs. In some cases, the grant includes an index that corresponds to one of a set configurations for the set of aggregated TTIs. In some cases, at least some of the set of aggregated TTIs are non-contiguous in time.

Location identifier **1230** may identify a location of an excluded TTI within the set of aggregated TTIs.

Resource utilizer **1235** may communicate via the resources of the communication channel over at least a subset of the set of aggregated TTIs based on the grant and the identified location of the excluded TTI, receive a first portion of a data transmission of the first TTI in the first set of symbols via a first receive beam associated with the first transmit beam and a second portion of the data transmission of the first TTI in the second set of symbols via a second receive beam associated with the second transmit beam, and transmit the channel state information (CSI) and at least a portion of the multi-TTI acknowledgment transmission within the updated location of the acknowledgment TTI. In some cases, communicating via the resources of the communication channel includes: identifying a first set of symbols of the first TTI associated with a synchronization signal to be transmitted via a first transmit beam and a second set of symbols of the first TTI to be transmitted via a second transmit beam.

Transmitter **1220** may transmit signals generated by other components of the device. In some examples, the transmitter **1220** may be collocated with a receiver **1210** in a transceiver module. For example, the transmitter **1220** may be an example of aspects of the transceiver **1435** described with reference to FIG. **14**. The transmitter **1220** may utilize a single antenna or a set of antennas.

FIG. **13** shows a block diagram **1300** of a UE communications manager **1305** that supports discontinuous scheduling in accordance with aspects of the present disclosure. The UE communications manager **1305** may be an example of aspects of a UE communications manager **1115**, a UE communications manager **1215**, or a UE communications manager **1415** described with reference to FIGS. **11**, **12**, and **14**.

UE communications manager **1305** may receive information from a receiver (e.g., receiver **1110**, receiver **1210**, or transceiver **1435** in FIGS. **11**, **12**, and **14**, respectively), and may direct the received information to one or more components of UE communications manager **1305**. Based at least in part on the information, UE communications manager **1305** may monitor a control channel for a grant of resources of a communication channel over a plurality of aggregated TTIs, identify a location of an excluded TTI within the plurality of aggregated TTIs, and communicate via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs based at least in part on the grant and the identified location of the excluded TTI. UE communications manager **1305** may communicate via the resources of the communication channel by transmitting information via a transmitter (e.g., transmitter **1120**, transmitter **1220**, or transceiver **1435** in FIGS. **11**, **12**, and **14**, respectively).

The UE communications manager **1305** may include monitor component **1310**, location identifier **1315**, resource utilizer **1320**, adjuster component **1325**, reassigner component **1330**, counter **1335**, and acknowledgment component **1340**. Each of these modules may communicate, directly or indirectly, with one another (e.g., via one or more buses).

Monitor component **1310** may monitor a control channel for a grant of resources of a communication channel over a set of aggregated transmission time intervals (TTIs). In some cases, the grant includes a bit sequence identifying the set of aggregated TTIs. In some cases, the grant includes an index that corresponds to one of a set configurations for the set of aggregated TTIs. In some cases, at least some of the set of aggregated TTIs are non-contiguous in time.

Monitor component **1310** may receive, via receiver **1110**, **1210**, or **1435**, a grant of resources **1345** from a base station **105**. In some cases, monitor component **1310** may obtain the bit sequence and/or the index from the grant of resources **1345**, and may pass, via an electrical connection, TTI information **1350** to location identifier **1315**. TTI information **1350** may include an indication of the set of aggregated TTIs and/or an indication of the configuration of the set of aggregated TTIs. In some cases, monitor component **1310** may pass, via electrical connection, an indication **1355** of the grant of resources **1345** to resource utilizer **1320**.

Location identifier **1315** may receive TTI information **1350** from monitor component **1310** and, based on the received TTI information **1350**, identify a location of an excluded TTI within the set of aggregated TTIs. Location identifier **1315** may pass, via an electrical connection, the identified location **1360** of the excluded TTI to resource utilizer **1320**, adjuster component **1325**, and/or counter **1335**.

Adjuster component **1325** may receive the identified location **1360** of the excluded TTI, adjust an end TTI for the set of aggregated TTIs based on the location of the excluded TTI, and adjust a TTI number for the set of aggregated TTIs based on the location of the excluded TTI. In some cases, adjuster component **1325** may pass, via an electrical connection, an indication of the adjusted end TTI **1370** to resource utilizer **1320**.

Counter **1335** may receive the identified location **1360** of the excluded TTI and may maintain a TTI count of communicated TTIs of the set of aggregated TTIs based at least in part on the excluded TTI in the TTI count. In some cases, counter **1335** may pass, via an electrical connection, the TTI count **1395** to reassigner component **1330**.

Reassigner component **1330** may receive, via receiver **1110**, **1210**, or **1435**, a TTI reassignment indication **1390** reassigning at least a portion of a first TTI of the set of aggregated TTIs. Reassigner component **1330** may process the TTI reassignment indication, determine that the TTI reassignment indication is received after a beginning of transmission of a multi-TTI acknowledgment transmission, and adjust TTIs included in the set of aggregated TTIs based on the TTI reassignment indication.

In some examples, reassigner component **1330** may determine a location of the first TTI within the set of aggregated TTIs, and shift a subset of the set of aggregated TTIs, that occurs after the first TTI, back by at least one TTI based on the determined location of the first TTI. In some cases, reassigner component **1330** may determine that a location of

an acknowledgment TTI has been changed to an updated location based on adjusting the TTIs included in the set of aggregated TTIs. In some examples, reassigner component **1330** may determine that the at least the portion of the first TTI is being punctured, determine that the TTI reassignment indication is received after a beginning of a multi-TTI acknowledgment transmission, and cancel a remainder of the multi-TTI acknowledgment transmission. In some examples, reassigner component **1330** may determine that the TTI reassignment indication is received after a beginning of transmission of a multi-TTI acknowledgment transmission.

Reassigner component **1330** may determine that a location of an acknowledgment TTI has changed to an updated location that overlaps with a TTI in which CSI is scheduled for transmission. In some cases, determining that the location of the acknowledgment TTI has changed includes: determining that the CSI is scheduled to be transmitted within one of the adjusted set of aggregated TTIs. In some cases, determining that the location of the acknowledgment TTI has changed includes: determining that the updated location of the acknowledgment TTI is in a same TTI as a TTI scheduled to transport the CSI. In some cases, reassigner component **1330** may pass, via an electrical connection, adjusted TTI information **1380** to resource utilizer **1320**.

Acknowledgement component **1340** may receive, via receiver **1110**, **1210**, or **1435**, the TTI reassignment indication **1390** reassigning at least a portion of a first TTI of the set of aggregated TTIs. Acknowledgment component **1340** may communicate an acknowledgment of the TTI reassignment indication **1390** prior to a beginning TTI of the set of aggregated TTIs. In some examples, acknowledgment component **1340** may communicate a merged feedback message that includes CSI and acknowledgement data within the updated location, where the merged feedback message includes at least a portion of the multi-TTI acknowledgment transmission. In some cases, acknowledgement component **1340** may pass, via an electrical connection, the merged feedback message **1385** to resource utilizer **1320**.

Resource utilizer **1320** may receive the indication **1355** of the grant of resources **1345**, the identified location **1360** of the excluded TTI, the merged feedback message **1385**, and the adjusted TTI information **1380**. Resource utilizer **1320** may communicate via the resources of the communication channel over at least a subset of the set of aggregated TTIs based on the grant (e.g., based on the indication **1355** of the grant of resources **1345**) and the identified location **1360** of the excluded TTI. Resource utilizer **1320** may receive, via receiver **1110**, **1210**, or **1435**, a first portion of a data transmission **1365** of the first TTI in the first set of symbols via a first receive beam associated with the first transmit beam. Resource utilizer **1320** may receive, via receiver **1110**, **1210**, or **1435**, a second portion of the data transmission **1368** of the first TTI in the second set of symbols via a second receive beam associated with the second transmit beam.

Resource utilizer **1320** may transmit, via transmitter **1120**, **1220**, or transceiver **1435**, the CSI and at least a portion of the multi-TTI acknowledgment transmission **1375** (e.g., based on the merged feedback message **1385**) within the updated location of the acknowledgment TTI. In some cases, communicating via the resources of the communication channel includes identifying a first set of symbols of the first TTI associated with a synchronization signal to be transmitted via a first transmit beam and a second set of symbols of the first TTI to be transmitted via a second transmit beam.

FIG. **14** shows a diagram of a system **1400** including a device **1405** that supports discontinuous scheduling in accordance with aspects of the present disclosure. Device **1405** may be an example of or include the components of wireless device **1105**, wireless device **1205**, or a UE **115** as described above, e.g., with reference to FIGS. **11** and **12**. Device **1405** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, including UE communications manager **1415**, processor **1420**, memory **1425**, software **1430**, transceiver **1435**, antenna **1440**, and I/O controller **1445**. These components may be in electronic communication via one or more buses (e.g., bus **1410**). Device **1405** may communicate wirelessly with one or more base stations **105**.

Processor **1420** may include an intelligent hardware device, (e.g., a general-purpose processor, a DSP, a central processing unit (CPU), a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some cases, processor **1420** may be configured to operate a memory array using a memory controller. In other cases, a memory controller may be integrated into processor **1420**. Processor **1420** may be configured to execute computer-readable instructions stored in a memory to perform various functions (e.g., functions or tasks supporting discontinuous scheduling).

Memory **1425** may include random access memory (RAM) and read only memory (ROM). The memory **1425** may store computer-readable, computer-executable software **1430** including instructions that, when executed, cause the processor to perform various functions described herein. In some cases, the memory **1425** may contain, among other things, a basic input/output system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

Software **1430** may include code to implement aspects of the present disclosure, including code to support discontinuous scheduling. Software **1430** may be stored in a non-transitory computer-readable medium such as system memory or other memory. In some cases, the software **1430** may not be directly executable by the processor but may cause a computer (e.g., when compiled and executed) to perform functions described herein.

Transceiver **1435** may communicate bi-directionally, via one or more antennas, wired, or wireless links as described above. For example, the transceiver **1435** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **1435** may also include a modem to modulate the packets and provide the modulated packets to the antennas for transmission, and to demodulate packets received from the antennas.

In some cases, the wireless device may include a single antenna **1440**. However, in some cases the device may have more than one antenna **1440**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions.

I/O controller **1445** may manage input and output signals for device **1405**. I/O controller **1445** may also manage peripherals not integrated into device **1405**. In some cases, I/O controller **1445** may represent a physical connection or port to an external peripheral. In some cases, I/O controller **1445** may utilize an operating system such as iOS®, ANDROID®, MS-DOS®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In other cases, I/O controller **1445** may represent or interact with a modem, a keyboard, a mouse, a touchscreen, or a

similar device. In some cases, I/O controller **1445** may be implemented as part of a processor. In some cases, a user may interact with device **1405** via I/O controller **1445** or via hardware components controlled by I/O controller **1445**.

FIG. **15** shows a block diagram **1500** of a wireless device **1505** that supports discontinuous scheduling in accordance with aspects of the present disclosure. Wireless device **1505** may be an example of aspects of a base station **105** as described herein. Wireless device **1505** may include receiver **1510**, base station communications manager **1515**, and transmitter **1520**. Wireless device **1505** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

Receiver **1510** may receive information such as packets, user data, or control information associated with various information channels (e.g., control channels, data channels, and information related to discontinuous scheduling, etc.). Information may be passed on to other components of the device. The receiver **1510** may be communicatively coupled, and pass information, to the UE Communications manager via link **1550**. The receiver **1510** may be an example of aspects of the transceiver **1835** described with reference to FIG. **18**. The receiver **1510** may utilize a single antenna or a set of antennas.

Base station communications manager **1515** may be an example of aspects of the base station communications manager **1815** described with reference to FIG. **18**.

Base station communications manager **1515** and/or at least some of its various sub-components may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions of the base station communications manager **1515** and/or at least some of its various sub-components may be executed by a general-purpose processor, a DSP, an ASIC, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described in the present disclosure. The base station communications manager **1515** and/or at least some of its various sub-components may be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations by one or more physical devices. In some examples, base station communications manager **1515** and/or at least some of its various sub-components may be a separate and distinct component in accordance with various aspects of the present disclosure. In other examples, base station communications manager **1515** and/or at least some of its various sub-components may be combined with one or more other hardware components, including but not limited to an I/O component, a transceiver, a network server, another computing device, one or more other components described in the present disclosure, or a combination thereof in accordance with various aspects of the present disclosure.

Base station communications manager **1515** may transmit, to a UE, a grant of resources of a communication channel over a set of aggregated transmission time intervals (TTIs), identify a location of an excluded TTI within the set of aggregated TTIs, and communicate with the UE via the resources of the communication channel over at least a subset of the set of aggregated TTIs based on the grant and the location of the excluded TTI. The base station communications manager **1515** may be communicatively coupled, and pass information, to the transmitter **1520**.

Transmitter **1520** may transmit signals generated by other components of the device. In some examples, the transmitter **1520** may be collocated with a receiver **1510** in a transceiver module. For example, the transmitter **1520** may be an example of aspects of the transceiver **1835** described with reference to FIG. **18**. The transmitter **1520** may be communicatively coupled with, and receive information from, the UE Communications manager via link **1555**. The transmitter **1520** may utilize a single antenna or a set of antennas.

FIG. **16** shows a block diagram **1600** of a wireless device **1605** that supports discontinuous scheduling in accordance with aspects of the present disclosure. Wireless device **1605** may be an example of aspects of a wireless device **1505** or a base station **105** as described with reference to FIG. **15**. Wireless device **1605** may include receiver **1610**, base station communications manager **1615**, and transmitter **1620**. Wireless device **1605** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

Receiver **1610** may receive information such as packets, user data, or control information associated with various information channels (e.g., control channels, data channels, and information related to discontinuous scheduling, etc.). Information may be passed on to other components of the device. The receiver **1610** may be an example of aspects of the transceiver **1835** described with reference to FIG. **18**. The receiver **1610** may utilize a single antenna or a set of antennas.

Base station communications manager **1615** may be an example of aspects of the base station communications manager **1815** described with reference to FIG. **18**.

Base station communications manager **1615** may also include grant component **1625**, location identifier **1630**, and resource utilizer **1635**.

Grant component **1625** may transmit, to a UE, a grant of resources of a communication channel over a set of aggregated transmission time intervals (TTIs). In some cases, the grant includes a bit sequence identifying the set of aggregated TTIs. In some cases, the grant includes an index that corresponds to one of a set configurations for the set of aggregated TTIs. In some cases, at least some of the set of aggregated TTIs are non-contiguous in time.

Location identifier **1630** may identify a location of an excluded TTI within the set of aggregated TTIs.

Resource utilizer **1635** may communicate with the UE via the resources of the communication channel over at least a subset of the set of aggregated TTIs based on the grant and the location of the excluded TTI, identify a first set of symbols of the first TTI associated with a synchronization signal to be transmitted via a first transmit beam and a second set of symbols of the first TTI to be transmitted via a second transmit beam, and transmit a first portion of a data transmission of the first TTI in the first set of symbols via the first transmit beam and a second portion of the data transmission of the first TTI in the second set of symbols via the second transmit beam.

Transmitter **1620** may transmit signals generated by other components of the device. In some examples, the transmitter **1620** may be collocated with a receiver **1610** in a transceiver module. For example, the transmitter **1620** may be an example of aspects of the transceiver **1835** described with reference to FIG. **18**. The transmitter **1620** may utilize a single antenna or a set of antennas.

FIG. **17** shows a block diagram **1700** of a base station communications manager **1705** that supports discontinuous scheduling in accordance with aspects of the present disclosure. The base station communications manager **1705** may

be an example of aspects of a base station communications manager **1515**, **1615**, or **1815** described with reference to FIGS. **15**, **16**, and **18**.

The base station communications manager **1705** may receive information from a receiver (e.g., receiver **1510**, receiver **1610**, or transceiver **1835** in FIGS. **15**, **16**, and **18**, respectively), and may direct the received information to one or more components of base station communications manager **1705**. Based at least in part on the information, base station communications manager **1705** may transmit, to a UE, a grant of resources of a communication channel over a plurality of aggregated TTIs, identify a location of an excluded TTI within the plurality of aggregated TTIs, and communicate with the UE via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs based at least in part on the grant and the location of the excluded TTI. Base station communications manager **1705** may transmit information to the UE via a transmitter (e.g., transmitter **1520**, transmitter **1620**, or transceiver **1835** in FIGS. **15**, **16**, and **18**, respectively).

The base station communications manager **1705** may include grant component **1710**, resource utilizer **1715**, adjuster component **1720**, location identifier **1725**, acknowledgment component **1730**, transport block component **1735**, and reassigner component **1740**. Each of these modules may communicate, directly or indirectly, with one another (e.g., via one or more buses).

Grant component **1710** may receive a request for resources **1760** from a UE and transmit (e.g., via transmitter **1520**, transmitter **1620**, or transceiver **1835**), to the UE, a grant **1755** of resources of a communication channel over a set of aggregated transmission time intervals (TTIs). In some cases, the grant **1755** includes a bit sequence identifying the set of aggregated TTIs. In some cases, the grant **1755** includes an index that corresponds to one of a set configurations for the set of aggregated TTIs. In some cases, at least some of the set of aggregated TTIs are non-contiguous in time. In some cases, grant component **1710** may pass, via an electrical connection, the grant **1755** to resource utilizer **1715** and location identifier **1725**. In some cases, grant component **1710** may pass, via an electrical connection, the request for resources **1760** to transport block component **1735** and location identifier **1725**.

Location identifier **1725** may receive the request for resources **1760** and identify a location of an excluded TTI within the set of aggregated TTIs. In some cases, location identifier **1725** may pass, via an electrical connection, the identified location **1790** of the excluded TTI to grant component **1710**, resource utilizer **1715**, and adjuster component **1720**.

Resource utilizer **1715** may receive the grant **1755** and the identified location **1790** of the excluded TTI and may communicate with the UE via the resources of the communication channel over at least a subset of the set of aggregated TTIs based on the grant **1755** and the identified location **1790** of the excluded TTI. Resource utilizer **1715** may identify a first set of symbols of the first TTI associated with a synchronization signal to be transmitted via a first transmit beam and a second set of symbols of the first TTI to be transmitted via a second transmit beam, and transmit (e.g., via transmitter **1520**, transmitter **1620**, or transceiver **1835**) a first portion of a data transmission **1765** of the first TTI in the first set of symbols via the first transmit beam and a second portion of the data transmission **1770** of the first TTI in the second set of symbols via the second transmit beam. Resource utilizer **1715** may receive and make scheduling decisions based on merged feedback message **1775** from the acknowledgment component **1730**.

Adjuster component **1720** may receive the location **1790** of the excluded TTI, and may adjust an end TTI for the set of aggregated TTIs based on the location of the excluded TTI, adjust a TTI number for the set of aggregated TTIs based on the location of the excluded TTI, adjust TTIs included in the set of aggregated TTIs based on the TTI reassignment indication, determine a location of the first TTI within the set of aggregated TTIs, and shift a subset of the set of aggregated TTIs, that occurs after the first TTI, back by at least one TTI based on the determined location. In some cases, adjuster component **1720** may pass, via an electrical connection, an indication **1780** of the adjusted end TTI to resource utilizer **1715**. In some cases, adjuster component **1720** may pass, via an electrical connection, an indication **1785** of the location of the first TTI to reassigner component **1740**.

Reassigner component **1740** may generate a TTI reassignment indication **1750** reassigning at least a portion of a first TTI of the set of aggregated TTIs, transmit the TTI reassignment indication **1750** to the UE (e.g., via transmitter **1520**, transmitter **1620**, or transceiver **1835**), and determine that the at least the portion of the first TTI is being punctured. In some cases, reassigner component **1740** may receive, from the UE, an indication **1745** of a capability of the UE. In some cases, generating the TTI reassignment indication includes: generating the TTI reassignment indication based on determining that a capability of the UE (e.g., based on the indication **1745** of the capability) satisfies a threshold. In some cases, determining that the capability of the UE satisfies the threshold includes: determining that a response time of the UE satisfies the threshold. In some cases, reassigner component **1740** may pass, via an electrical connection, the TTI reassignment indication **1750** to acknowledgement component **1730**.

Acknowledgment component **1730** may receive a merged feedback message that includes CSI and acknowledgement data and receive an acknowledgment of the TTI reassignment indication **1750** prior to a beginning TTI of the set of aggregated TTIs. In some cases, acknowledgement component **1730** may pass, via an electrical connection, the merged feedback message **1775** to the resource utilizer **1715**.

Transport block component **1735** may receive the request for resources **1760** from the grant component **1710** and communicate a transport block size that excludes the first TTI from a calculation of the transport block size. In some cases, transport block component **1735** may transmit the transport block size **1795** to a UE (e.g., via transmitter **1520**, transmitter **1620**, or transceiver **1835**).

FIG. **18** shows a diagram of a system **1800** including a device **1805** that supports discontinuous scheduling in accordance with aspects of the present disclosure. Device **1805** may be an example of or include the components of base station **105** as described above, e.g., with reference to FIG. **1**. Device **1805** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, including base station communications manager **1815**, processor **1820**, memory **1825**, software **1830**, transceiver **1835**, antenna **1840**, network communications manager **1845**, and inter-station communications manager **1850**. These components may be in electronic communication via one or more buses (e.g., bus **1810**). Device **1805** may communicate wirelessly with one or more UEs **115**.

Processor **1820** may include an intelligent hardware device, (e.g., a general-purpose processor, a DSP, a CPU, a

microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some cases, processor **1820** may be configured to operate a memory array using a memory controller. In other cases, a memory controller may be integrated into processor **1820**. Processor **1820** may be configured to execute computer-readable instructions stored in a memory to perform various functions (e.g., functions or tasks supporting discontinuous scheduling).

Memory **1825** may include RAM and ROM. The memory **1825** may store computer-readable, computer-executable software **1830** including instructions that, when executed, cause the processor to perform various functions described herein. In some cases, the memory **1825** may contain, among other things, a BIOS which may control basic hardware or software operation such as the interaction with peripheral components or devices.

Software **1830** may include code to implement aspects of the present disclosure, including code to support discontinuous scheduling. Software **1830** may be stored in a non-transitory computer-readable medium such as system memory or other memory. In some cases, the software **1830** may not be directly executable by the processor but may cause a computer (e.g., when compiled and executed) to perform functions described herein.

Transceiver **1835** may communicate bi-directionally, via one or more antennas, wired, or wireless links as described above. For example, the transceiver **1835** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **1835** may also include a modem to modulate the packets and provide the modulated packets to the antennas for transmission, and to demodulate packets received from the antennas.

In some cases, the wireless device may include a single antenna **1840**. However, in some cases the device may have more than one antenna **1840**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions.

Network communications manager **1845** may manage communications with the core network (e.g., via one or more wired backhaul links). For example, the network communications manager **1845** may manage the transfer of data communications for client devices, such as one or more UEs **115**.

Inter-station communications manager **1850** may manage communications with other base station **105**, and may include a controller or scheduler for controlling communications with UEs **115** in cooperation with other base stations **105**. For example, the inter-station communications manager **1850** may coordinate scheduling for transmissions to UEs **115** for various interference mitigation techniques such as beamforming or joint transmission. In some examples, inter-station communications manager **1850** may provide an X2 interface within an Long Term Evolution (LTE)/LTE-A wireless communication network technology to provide communication between base stations **105**.

FIG. **19** shows a flowchart illustrating a method **1900** for discontinuous scheduling in accordance with aspects of the present disclosure. The operations of method **1900** may be implemented by a UE **115** or its components as described herein. For example, the operations of method **1900** may be performed by a UE communications manager as described with reference to FIGS. **11** through **14**. In some examples, a UE **115** may execute a set of codes to control the functional elements of the device to perform the functions described below. Additionally or alternatively, the UE **115** may perform aspects of the functions described below using special-purpose hardware.

At block **1905** the UE **115** may monitor a control channel for a grant of resources of a communication channel over a plurality of aggregated transmission time intervals (TTIs). In some examples, UE **115** may monitor the control channel using a receiver that may detect an incoming signal, e.g., a grant. The operations of block **1905** may be performed according to the methods described herein. In some examples, the UE **115** may identify time-frequency resources over which the control channel is transmitted, demodulate a transmission over those time-frequency resources, decode the demodulated transmission to obtain bits that indicate the downlink transmission. In certain examples, aspects of the operations of block **1905** may be performed by a monitor component as described with reference to FIGS. **11** through **14**.

At block **1910** the UE **115** may identify a location of an excluded TTI within the plurality of aggregated TTIs. In some examples, the UE **115** may identify the location of an excluded TTI based on information included in the grant received at block **1905**, or based on configuration information received within RRC signaling. The operations of block **1910** may be performed according to the methods described herein. In some examples, the UE **115** may receive, from the base station **105** via receiver **1110** or **1210**, an indication of the location of the excluded TTI in a DCI or via RRC signaling. In certain examples, aspects of the operations of block **1910** may be performed by a location identifier as described with reference to FIGS. **11** through **14**.

At block **1915** the UE **115** may communicate via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs based at least in part on the grant and the identified location of the excluded TTI. In some examples, UE **115** may communicate by transmitting or receiving, using a transmitter or receiver as described in FIGS. **11-12**, a signal using time-frequency resources associated with the communication channel. The operations of block **1915** may be performed according to the methods described herein. In some examples, the UE **115** may determine a set of aggregated TTIs corresponding to a grant based on a start TTI indication, and an end TTI indication or a TTI number indication. The UE **115** may identify in which TTIs resources have been allocated to the UE **115**, and may communicate within the allocated resources and corresponding TTIs. In certain examples, aspects of the operations of block **1915** may be performed by a resource utilizer as described with reference to FIGS. **11** through **14**.

FIG. **20** shows a flowchart illustrating a method **2000** for discontinuous scheduling in accordance with aspects of the present disclosure. The operations of method **2000** may be implemented by a UE **115** or its components as described herein. For example, the operations of method **2000** may be performed by a UE communications manager as described with reference to FIGS. **11** through **14**. In some examples, a UE **115** may execute a set of codes to control the functional elements of the device to perform the functions described below. Additionally or alternatively, the UE **115** may perform aspects of the functions described below using special-purpose hardware.

At block **2005** the UE **115** may monitor a control channel for a grant of resources of a communication channel over a plurality of aggregated transmission time intervals (TTIs). In some examples, UE **115** may monitor the control channel using a receiver that may detect an incoming signal, e.g., a

grant. The operations of block **2005** may be performed according to the methods described herein. In some examples, the UE **115** may identify time-frequency resources over which the control channel is transmitted, demodulate a transmission over those time-frequency resources, decode the demodulated transmission to obtain bits that indicate the downlink transmission. In certain examples, aspects of the operations of block **2005** may be performed by a monitor component as described with reference to FIGS. **11** through **14**.

At block **2010** the UE **115** may identify a location of an excluded TTI within the plurality of aggregated TTIs. In some examples, the UE **115** may identify the location of an excluded TTI based on information included in the grant received at block **1905**, or based on configuration information received within RRC signaling. The operations of block **2010** may be performed according to the methods described herein. In some examples, the UE **115** may receive, from the base station **105** via receiver **1110** or **1210**, an indication of a location of an excluded TTI in a DCI or via RRC signaling. In certain examples, aspects of the operations of block **2010** may be performed by a location identifier as described with reference to FIGS. **11** through **14**.

At block **2015** the UE **115** may process a TTI reassignment indication reassigning at least a portion of a first TTI of the plurality of aggregated TTIs. In some examples, UE **115** may receive the TTI reassignment indication from a base station **105** via a receiver **1110** or **1210**. UE **115** may process the TTI reassignment indication by identifying, based on the TTI reassignment indication, a TTI that is to be reassigned. The operations of block **2015** may be performed according to the methods described herein. In certain examples, aspects of the operations of block **2015** may be performed by a reassigner component as described with reference to FIGS. **11** through **14**.

At block **2020** the UE **115** may adjust TTIs included in the plurality of aggregated TTIs by shifting a subset of the set of aggregated TTIs, that occurs after the first TTI, back by at least one TTI. The UE **115** may shift the subset of the set of aggregated TTIs by changing an index into the set of aggregated TTIs, for example. The operations of block **2020** may be performed according to the methods described herein. In some examples, the UE **115** may determine a set of aggregated TTIs corresponding to a grant, determine a location of a TTI within the grant being reassigned, and shift the subsequent TTIs in the set of aggregated TTIs by at least one TTI. In certain examples, aspects of the operations of block **2020** may be performed by a reassigner component as described with reference to FIGS. **11** through **14**.

At block **2025** the UE **115** may communicate via the resources of the communication channel over at least a subset of the adjusted plurality of aggregated TTIs based at least in part on the grant and the identified location of the excluded TTI. In some examples, UE **115** may communicate by transmitting or receiving, using a transmitter or receiver as described in FIGS. **11-12**, a signal using time-frequency resources associated with the communication channel. The operations of block **2025** may be performed according to the methods described herein. The UE **115** may, for example, communicate uplink data and/or receive downlink data within the allocated resources and corresponding TTIs. In certain examples, aspects of the operations of block **2025** may be performed by a resource utilizer as described with reference to FIGS. **11** through **14**.

FIG. **21** shows a flowchart illustrating a method **2100** for discontinuous scheduling in accordance with aspects of the present disclosure. The operations of method **2100** may be implemented by a base station **105** or its components as described herein. For example, the operations of method **2100** may be performed by a base station communications manager as described with reference to FIGS. **15** through **18**. In some examples, a base station **105** may execute a set of codes to control the functional elements of the device to perform the functions described below. Additionally or alternatively, the base station **105** may perform aspects of the functions described below using special-purpose hardware.

At block **2105** the base station **105** may transmit, to a user equipment (UE), a grant of resources of a communication channel over a plurality of aggregated transmission time intervals (TTIs). The base station may transmit the grant using a transmitter, for example. The operations of block **2105** may be performed according to the methods described herein. In some examples, the station **105** may identify time-frequency resources over which the control channel is to be transmitted and modulate a transmission over those time-frequency resources. In certain examples, aspects of the operations of block **2105** may be performed by a grant component as described with reference to FIGS. **15** through **18**.

At block **2110** the base station **105** may identify a location of an excluded TTI within the plurality of aggregated TTIs. The operations of block **2110** may be performed according to the methods described herein. In some examples, the base station **105** may determine to transmit data at periodic or defined intervals, and may select a location of an excluded TTI for transporting the data (e.g., select a sync slot, a RACH slot, or the like). In certain examples, aspects of the operations of block **2110** may be performed by a location identifier as described with reference to FIGS. **15** through **18**.

At block **2115** the base station **105** may communicate with the UE via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs based at least in part on the grant and the location of the excluded TTI. In some examples, base station **105** may communicate by transmitting or receiving, using a transmitter or receiver, a signal using time-frequency resources associated with the communication channel. The operations of block **2115** may be performed according to the methods described herein. In some examples, the base station **105** may determine a set of aggregated TTIs corresponding to a grant and transmit at least a portion of a transport block within each TTI within the set of aggregated TTIs. In certain examples, aspects of the operations of block **2115** may be performed by a resource utilizer as described with reference to FIGS. **15** through **18**.

FIG. **22** shows a flowchart illustrating a method **2200** for discontinuous scheduling in accordance with aspects of the present disclosure. The operations of method **2200** may be implemented by a base station **105** or its components as described herein. For example, the operations of method **2200** may be performed by a base station communications manager as described with reference to FIGS. **15** through **18**. In some examples, a base station **105** may execute a set of codes to control the functional elements of the device to perform the functions described below. Additionally or alternatively, the base station **105** may perform aspects of the functions described below using special-purpose hardware.

At block **2205** the base station **105** may transmit, to a user equipment (UE), a grant of resources of a communication channel over a plurality of aggregated transmission time intervals (TTIs). The base station may transmit the grant

using a transmitter **1520**,**1620**, or transceiver **1835**, for example. The operations of block **2205** may be performed according to the methods described herein. In some examples, the base station **105** may identify time-frequency resources over which the control channel is to be transmitted and cause transmitter **1520** or **1620** to modulate a transmission over those time-frequency resources. In certain examples, aspects of the operations of block **2205** may be performed by a grant component as described with reference to FIGS. **15** through **18**.

At block **2210** the base station **105** may identify a location of an excluded TTI within the plurality of aggregated TTIs. The operations of block **2210** may be performed according to the methods described herein. In some examples, the base station **105** may determine to transmit data at periodic or defined intervals, and may select a location of an excluded TTI for transporting the data (e.g., select a sync slot, a RACH slot, or the like). In certain examples, aspects of the operations of block **2210** may be performed by a location identifier as described with reference to FIGS. **15** through **18**.

At block **2215** the base station **105** may generate a TTI reassignment indication reassigning at least a portion of a first TTI of the plurality of aggregated TTIs based at least in part on determining that a capability of the UE satisfies a threshold. The operations of block **2215** may be performed according to the methods described herein. In some examples, the base station **105** may determine to transmit priority data (e.g., URLLC) in a TTI that was previously allocated to a UE **115** in a previously transmitted grant. The station **105** may generate a TTI reassignment indication to reassign the TTI. In certain examples, aspects of the operations of block **2215** may be performed by a reassigner component as described with reference to FIGS. **15** through **18**.

At block **2220** the base station **105** may transmit the TTI reassignment indication to the UE. The base station **105** may transmit the TTI reassignment indication via a transmitter, for example. The operations of block **2220** may be performed according to the methods described herein. The base station **105** may encode and modulate bits for transmission to the UE **115** via a wireless communication channel. In certain examples, aspects of the operations of block **2220** may be performed by a reassigner component as described with reference to FIGS. **15** through **18**.

At block **2225** the base station **105** may communicate with the UE via the resources of the communication channel over at least a subset of the adjusted plurality of aggregated TTIs based at least in part on the grant and the location of the excluded TTI. In some examples, base station **105** may communicate by transmitting or receiving, using a transmitter or receiver, a signal using time-frequency resources associated with the communication channel. The operations of block **2225** may be performed according to the methods described herein. In some examples, the base station **105** may determine a set of adjusted aggregated TTIs corresponding to a grant and a TTI reassignment indication, and transmit, via transmitter **1520**, **1620**, or transceiver **1835**, at least a portion of a transport block within each TTI within the set of adjusted aggregated TTIs. In certain examples, aspects of the operations of block **2225** may be performed by a resource utilizer component as described with reference to FIGS. **15** through **18**.

FIG. **23** shows a flowchart illustrating a method **2300** for discontinuous scheduling in accordance with aspects of the present disclosure. The operations of method **2300** may be implemented by a UE **115** or its components as described herein. For example, the operations of method **2300** may be performed by a UE communications manager as described with reference to FIGS. **11** through **14**. In some examples, a UE **115** may execute a set of codes to control the functional elements of the device to perform the functions described below. Additionally or alternatively, the UE **115** may perform aspects of the functions described below using special-purpose hardware.

At block **2305**, the UE **115** may receive a grant of a set of aggregated TTIs. For example, the UE **115** may receive a grant of a set of aggregated TTIs from a base station **105**, via a receiver **1110** or **1210** of UE **115**. The grant may include, for example, a grant of resources of a communication channel over the set of aggregated TTIs. In certain examples, aspects of the operations of block **2305** may be performed by a monitor component as described with reference to FIGS. **11** through **14**.

At block **2310**, the UE **115** may identify a location of an excluded TTI in the set of aggregated TTIs. In some cases, the UE **115** may identify the location of the excluded TTI. In some examples, the UE **115** may identify the location of the excluded TTI based on an indication received from the base station **105** via a configuration in a master information block, a minimum system information block (mSIB), an other SIB (OSIB), RRC messaging, group-common DCI signaling, or the like. In some cases, the periodic or known intervals of such excluded TTIs may be preconfigured and the UE **115** may know to exclude such TTIs from the set of aggregated TTIs in the grant. In other examples, the grant may provide an explicit indication that excludes such TTIs from the grant of resources. In certain examples, aspects of the operations of block **2310** may be performed by a location identifier as described with reference to FIGS. **11** through **14**.

At block **2315**, the UE **115** may adjust the ending TTI of the set of aggregated TTIs based on the location of the excluded TTI. In some examples, the UE **115** may determine a set of aggregated TTIs corresponding to a grant, determine a location of a TTI within the grant being reassigned, and shift the subsequent TTIs in the set of aggregated TTIs by at least one TTI. In certain examples, aspects of the operations of block **2315** may be performed by a reassigner component as described with reference to FIGS. **11** through **14**.

At block **2320**, the UE **115** may begin communication (e.g., with the base station **105**) via the TTIs, e.g., UE **115** may begin communication via the resources of the communication channel over at least a subset of the set of aggregated TTIs, based on the grant and the identified location of the excluded TTI. In some examples, UE **115** may communicate by transmitting or receiving, using a transmitter or receiver as described in FIGS. **11-12**, a signal using time-frequency resources associated with the communication channel. In certain examples, aspects of the operations of block **2320** may be performed by a resource utilizer as described with reference to FIGS. **11** through **14**.

At block **2325**, the UE **115** may determine if the UE **115** has received a TTI reassignment indication (e.g., from base station **105**) reassigning at least a portion of a TTI of the set of aggregated TTIs.

If it is determined that the UE **115** has not received a TTI reassignment indication, the UE may return to block **2320** and continue communication over the subset of the set of aggregated TTIs.

If it is determined that the UE **115** has received a TTI reassignment indication, at block **2330**, the UE may communicate, to the base station **105**, an acknowledgement of

the reassignment indication, and may adjust the TTIs included in the set of aggregated TTIs based on the reassignment indication.

At block **2335**, the UE may communicate, with base station **105**, via the adjusted TTIs, e.g., UE **115** may begin communication via the resources of the communication channel over the adjusted set of aggregated TTIs. In some examples, UE **115** may communicate by transmitting or receiving, using a transmitter or receiver as described in FIGS. **11-12**, a signal using time-frequency resources associated with the communication channel using the adjusted set of aggregated TTIs. In certain examples, aspects of the operations of block **2335** may be performed by a resource utilizer as described with reference to FIGS. **11** through **14**.

It should be noted that the methods described above describe possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

Techniques described herein may be used for various wireless communications systems such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal frequency division multiple access (OFDMA), single carrier frequency division multiple access (SC-FDMA), and other systems. The terms "system" and "network" are often used interchangeably. A code division multiple access (CDMA) system may implement a radio technology such as CDMA2000, Universal Terrestrial Radio Access (UTRA), etc. CDMA2000 covers IS-2000, IS-95, and IS-856 standards. IS-2000 Releases may be commonly referred to as CDMA2000 1×, 1×, etc. IS-856 (TIA-856) is commonly referred to as CDMA2000 1×EV-DO, High Rate Packet Data (HRPD), etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. A TDMA system may implement a radio technology such as Global System for Mobile Communications (GSM).

An OFDMA system may implement a radio technology such as Ultra Mobile Broadband (UMB), Evolved UTRA (E-UTRA), Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM, etc. UTRA and E-UTRA are part of Universal Mobile Telecommunications System (UMTS). LTE and LTE-A are releases of UMTS that use E-UTRA. UTRA, E-UTRA, UMTS, LTE, LTE-A, NR, and GSM are described in documents from the organization named "3rd Generation Partnership Project" (3GPP). CDMA2000 and UMB are described in documents from an organization named "3rd Generation Partnership Project 2" (3GPP2). The techniques described herein may be used for the systems and radio technologies mentioned above as well as other systems and radio technologies. While aspects of an LTE or an NR system may be described for purposes of example, and LTE or NR terminology may be used in much of the description, the techniques described herein are applicable beyond LTE or NR applications.

In LTE/LTE-A networks, including such networks described herein, the term evolved node B (eNB) may be generally used to describe the base stations. The wireless communications system or systems described herein may include a heterogeneous LTE/LTE-A or NR network in which different types of eNBs provide coverage for various geographical regions. For example, each eNB, next generation NodeB (gNB), or base station may provide communication coverage for a macro cell, a small cell, or other types of cell. The term "cell" may be used to describe a base station, a carrier or component carrier associated with a base station, or a coverage area (e.g., sector, etc.) of a carrier or base station, depending on context.

Base stations may include or may be referred to by those skilled in the art as a base transceiver station, a radio base station, an access point, a radio transceiver, a NodeB, eNodeB (eNB), gNB, Home NodeB, a Home eNodeB, or some other suitable terminology. The geographic coverage area for a base station may be divided into sectors making up only a portion of the coverage area. The wireless communications system or systems described herein may include base stations of different types (e.g., macro or small cell base stations). The UEs described herein may be able to communicate with various types of base stations and network equipment including macro eNBs, small cell eNBs, gNBs, relay base stations, and the like. There may be overlapping geographic coverage areas for different technologies.

A macro cell generally covers a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by UEs with service subscriptions with the network provider. A small cell is a lower-powered base station, as compared with a macro cell, that may operate in the same or different (e.g., licensed, unlicensed, etc.) frequency bands as macro cells. Small cells may include pico cells, femto cells, and micro cells according to various examples. A pico cell, for example, may cover a small geographic area and may allow unrestricted access by UEs with service subscriptions with the network provider. A femto cell may also cover a small geographic area (e.g., a home) and may provide restricted access by UEs having an association with the femto cell (e.g., UEs in a closed subscriber group (CSG), UEs for users in the home, and the like). An eNB for a macro cell may be referred to as a macro eNB. An eNB for a small cell may be referred to as a small cell eNB, a pico eNB, a femto eNB, or a home eNB. An eNB may support one or multiple (e.g., two, three, four, and the like) cells (e.g., component carriers).

The wireless communications system or systems described herein may support synchronous or asynchronous operation. For synchronous operation, the base stations may have similar frame timing, and transmissions from different base stations may be approximately aligned in time. For asynchronous operation, the base stations may have different frame timing, and transmissions from different base stations may not be aligned in time. The techniques described herein may be used for either synchronous or asynchronous operations.

The downlink transmissions described herein may also be called forward link transmissions while the uplink transmissions may also be called reverse link transmissions. Each communication link described herein—including, for example, wireless communications system **100** and **200** of FIGS. **1** and **2**—may include one or more carriers, where each carrier may be a signal made up of multiple sub-carriers (e.g., waveform signals of different frequencies).

The description set forth herein, in connection with the appended drawings, describes example configurations and does not represent all the examples that may be implemented or that are within the scope of the claims. The term "exemplary" used herein means "serving as an example, instance, or illustration," and not "preferred" or "advantageous over other examples." The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances,

well-known structures and devices are shown in block diagram form in order to avoid obscuring the concepts of the described examples.

In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If just the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

The various illustrative blocks and modules described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration).

The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described above can be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations. Also, as used herein, including in the claims, "or" as used in a list of items (for example, a list of items prefaced by a phrase such as "at least one of" or "one or more of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an exemplary step that is described as "based on condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on."

Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that can be accessed by a general purpose or special purpose computer. By way of example, and not limitation, non-transitory computer-readable media may comprise RAM, ROM, electrically erasable programmable read only memory (EEPROM), compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that can be used to carry or store desired program code means in the form of instructions or data structures and that can be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include CD, laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

The description herein is provided to enable a person skilled in the art to make or use the disclosure. Various modifications to the disclosure will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein, but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. A method for wireless communication, comprising:

receiving, from a base station, control signaling that indicates configuration information corresponding to an excluded transmission time interval (TTI);

monitoring a control channel for a grant of resources of a communication channel over a plurality of aggregated TTIs;

identifying a location of the excluded TTI within the plurality of aggregated TTIs based at least in part on the control signaling; and

communicating with the base station via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs other than the excluded TTI based at least in part on the grant and the identified location of the excluded TTI.

2. The method of claim **1**, further comprising:

maintaining a TTI count of communicated TTIs of the plurality of aggregated TTIs based at least in part on the excluded TTI in the TTI count.

3. The method of claim **1**, further comprising:

adjusting an end TTI for the plurality of aggregated TTIs based at least in part on the location of the excluded TTI.

4. The method of claim **1**, further comprising:

adjusting a TTI number for the plurality of aggregated TTIs based at least in part on the location of the excluded TTI.

5. The method of claim **1**, further comprising:

processing a TTI reassignment indication reassigning at least a portion of a first TTI of the plurality of aggregated TTIs.

6. The method of claim 5, further comprising:
communicating an acknowledgment of the TTI reassignment indication prior to a beginning TTI of the plurality of aggregated TTIs.

7. The method of claim 5, further comprising:
determining that the at least the portion of the first TTI is being punctured.

8. The method of claim 5, further comprising:
adjusting TTIs included in the plurality of aggregated TTIs based at least in part on the TTI reassignment indication.

9. The method of claim 8, wherein adjusting the TTIs comprises:
determining a location of the first TTI within the plurality of aggregated TTIs; and
shifting a subset of the plurality of aggregated TTIs, that occurs after the first TTI, back by at least one TTI based at least in part on the determined location.

10. The method of claim 8, wherein communicating via the resources of the communication channel comprises:
identifying a first plurality of symbols of the first TTI associated with a synchronization signal to be transmitted via a first transmit beam and a second plurality of symbols of the first TTI to be transmitted via a second transmit beam; and
receiving a first portion of a data transmission of the first TTI in the first plurality of symbols via a first receive beam associated with the first transmit beam and a second portion of the data transmission of the first TTI in the second plurality of symbols via a second receive beam associated with the second transmit beam.

11. The method of claim 8, further comprising:
determining that a location of an acknowledgment TTI has been changed to an updated location based at least in part on adjusting the TTIs included in the plurality of aggregated TTIs; and
communicating a merged feedback message that includes channel state information (CSI) and acknowledgement data within the updated location.

12. The method of claim 11, wherein determining that the location of the acknowledgment TTI has changed comprises:
determining that the updated location of the acknowledgment TTI is in a same TTI as a TTI scheduled to transport the CSI.

13. The method of claim 11, wherein determining that the location of the acknowledgment TTI has changed comprises:
determining that the CSI is scheduled to be transmitted within one of the adjusted plurality of aggregated TTIs.

14. The method of claim 13, further comprising:
determining that the TTI reassignment indication is received after a beginning of a multi-TTI acknowledgment transmission; and
cancelling a remainder of the multi-TTI acknowledgment transmission.

15. The method of claim 13, further comprising:
determining that the TTI reassignment indication is received after a beginning of transmission of a multi-TTI acknowledgment transmission, wherein the merged feedback message comprises at least a portion of the multi-TTI acknowledgment transmission.

16. The method of claim 5, further comprising:
determining that a location of an acknowledgment TTI has changed to an updated location that overlaps with a TTI in which channel state information (CSI) is scheduled for transmission;
determining that the TTI reassignment indication is received after a beginning of transmission of a multi-TTI acknowledgment transmission; and
transmitting the CSI and at least a portion of the multi-TTI acknowledgment transmission within the updated location of the acknowledgment TTI.

17. The method of claim 1, wherein the grant comprises a bit sequence identifying the plurality of aggregated TTIs.

18. The method of claim 1, wherein the grant comprises an index that corresponds to one of a plurality of configurations for the plurality of aggregated TTIs.

19. The method of claim 1, wherein at least some of the plurality of aggregated TTIs are non-contiguous in time.

20. The method of claim 1, wherein at least a first symbol of the excluded TTI is configured for communication in an opposite link direction than a link direction of at least some of the plurality of aggregated TTIs.

21. A method for wireless communication at a base station, comprising:
transmitting, from the base station and to a user equipment (UE), control signaling that indicates configuration information corresponding to an excluded aggregated transmission time interval (TTI);
transmitting, to the UE, a grant of resources of a communication channel over a plurality of TTIs;
identifying a location of the excluded TTI within the plurality of aggregated TTIs based at least in part on the control signaling; and
communicating with the UE via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs other than the excluded TTI based at least in part on the grant and the location of the excluded TTI.

22. The method of claim 21, further comprising:
adjusting an end TTI for the plurality of aggregated TTIs based at least in part on the location of the excluded TTI.

23. The method of claim 21, further comprising:
adjusting a TTI number for the plurality of aggregated TTIs based at least in part on the location of the excluded TTI.

24. The method of claim 21, further comprising:
generating a TTI reassignment indication reassigning at least a portion of a first TTI of the plurality of aggregated TTIs.

25. The method of claim 24, further comprising:
adjusting TTIs included in the plurality of aggregated TTIs based at least in part on the TTI reassignment indication.

26. The method of claim 25, wherein adjusting the TTIs comprises:
determining a location of the first TTI within the plurality of aggregated TTIs; and
shifting a subset of the plurality of aggregated TTIs, that occurs after the first TTI, back by at least one TTI based at least in part on the determined location.

27. The method of claim 25, further comprising:
identifying a first plurality of symbols of the first TTI associated with a synchronization signal to be transmitted via a first transmit beam and a second plurality of symbols of the first TTI to be transmitted via a second transmit beam; and
transmitting a first portion of a data transmission of the first TTI in the first plurality of symbols via the first transmit beam and a second portion of the data transmission of the first TTI in the second plurality of symbols via the second transmit beam.

28. The method of claim 25, further comprising:
receiving a merged feedback message that includes channel state information (CSI) and acknowledgement data.

29. The method of claim 24, wherein generating the TTI reassignment indication comprises:
generating the TTI reassignment indication based at least in part on determining that a capability of the UE satisfies a threshold; and
transmitting the TTI reassignment indication to the UE.

30. The method of claim 29, wherein determining that the capability of the UE satisfies the threshold comprises:
determining that a response time of the UE satisfies the threshold.

31. The method of claim 24, further comprising:
receiving an acknowledgment of the TTI reassignment indication prior to a beginning TTI of the plurality of aggregated TTIs.

32. The method of claim 24, further comprising:
communicating a transport block size that excludes the first TTI from a calculation of the transport block size.

33. The method of claim 24, further comprising:
determining that the at least the portion of the first TTI is being punctured.

34. The method of claim 21, wherein the grant comprises a bit sequence identifying the plurality of aggregated TTIs.

35. The method of claim 21, wherein the grant comprises an index that corresponds to one of a plurality of configurations for the plurality of aggregated TTIs.

36. The method of claim 21, wherein at least some of the plurality of aggregated TTIs are non-contiguous in time.

37. An apparatus for wireless communication, comprising:
a processor,
memory in electronic communication with the processor; and
instructions stored in the memory and operable, when executed by the processor, to cause the apparatus to:
receive, from a base station, control signaling that indicates configuration information corresponding to an excluded transmission time interval (TTI);
monitor a control channel for a grant of resources of a communication channel over a plurality of aggregated TTIs;
identify a location of the excluded TTI within the plurality of aggregated TTIs based at least in part on the control signaling; and
communicate with the base station via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs other than the excluded TTI based at least in part on the grant and the identified location of the excluded TTI.

38. The apparatus of claim 37, wherein the instructions are further executable by the processor to:
maintain a TTI count of communicated TTIs of the plurality of aggregated TTIs based at least in part on the excluded TTI in the TTI count.

39. The apparatus of claim 37, wherein the instructions are further executable by the processor to:
adjust an end TTI for the plurality of aggregated TTIs based at least in part on the location of the excluded TTI.

40. The apparatus of claim 37, wherein the instructions are further executable by the processor to:
adjust a TTI number for the plurality of aggregated TTIs based at least in part on the location of the excluded TTI.

41. The apparatus of claim 37, wherein the instructions are further executable by the processor to:
process a TTI reassignment indication reassigning at least a portion of a first TTI of the plurality of aggregated TTIs.

42. The apparatus of claim 41, wherein the instructions are further executable by the processor to:
communicate an acknowledgment of the TTI reassignment indication prior to a beginning TTI of the plurality of aggregated TTIs.

43. The apparatus of claim 41, wherein the instructions are further executable by the processor to:
determine that the at least the portion of the first TTI is being punctured.

44. The apparatus of claim 41, wherein the instructions are further executable by the processor to:
adjust TTIs included in the plurality of aggregated TTIs based at least in part on the TTI reassignment indication.

45. The apparatus of claim 44, wherein adjusting the TTIs comprises instructions further executable to:
determine a location of the first TTI within the plurality of aggregated TTIs; and
shift a subset of the plurality of aggregated TTIs, that occurs after the first TTI, back by at least one TTI based at least in part on the determined location.

46. The apparatus of claim 44, wherein communicating via the resources of the shared channel comprises instructions further executable to:
identify a first plurality of symbols of the first TTI associated with a synchronization signal to be transmitted via a first transmit beam and a second plurality of symbols of the first TTI to be transmitted via a second transmit beam; and
receive a first portion of a data transmission of the first TTI in the first plurality of symbols via a first receive beam associated with the first transmit beam and a second portion of the data transmission of the first TTI in the second plurality of symbols via a second receive beam associated with the second transmit beam.

47. The apparatus of claim 44, wherein the instructions are further executable by the processor to:
determine that a location of an acknowledgment TTI has been changed to an updated location based at least in part on adjusting the TTIs included in the plurality of aggregated TTIs; and
communicate a merged feedback message that includes channel state information (CSI) and acknowledgement data within the updated location.

48. The apparatus of claim 47, wherein determining that the location of the acknowledgment TTI has changed comprises instructions further executable to:
determine that the updated location of the acknowledgment TTI is in a same TTI as a TTI scheduled to transport the CSI.

49. The apparatus of claim 47, wherein determining that the location of the acknowledgment TTI has changed comprises instructions further executable to:
determine that the CSI is scheduled to be transmitted within one of the adjusted plurality of aggregated TTIs.

50. The apparatus of claim 49, wherein the instructions are further executable by the processor to:
determine that the TTI reassignment indication is received after a beginning of a multi-TTI acknowledgment transmission; and
cancel a remainder of the multi-TTI acknowledgment transmission.

51. The apparatus of claim 49, wherein the instructions are further executable by the processor to:

determine that the TTI reassignment indication is received after a beginning of transmission of a multi-TTI acknowledgment transmission, wherein the merged feedback message comprises at least a portion of the multi-TTI acknowledgment transmission.

52. The apparatus of claim 41, wherein the instructions are further executable by the processor to:

determine that a location of an acknowledgment TTI has changed to an updated location that overlaps with a TTI in which channel state information (CSI) is scheduled for transmission;

determine that the TTI reassignment indication is received after a beginning of transmission of a multi-TTI acknowledgment transmission; and

transmit the CSI and at least a portion of the multi-TTI acknowledgment transmission within the updated location of the acknowledgment TTI.

53. The apparatus of claim 37, wherein the grant comprises a bit sequence identifying the plurality of aggregated TTIs.

54. The apparatus of claim 37, wherein the grant comprises an index that corresponds to one of a plurality of configurations for the plurality of aggregated TTIs.

55. The apparatus of claim 37, wherein at least some of the plurality of aggregated TTIs are non-contiguous in time.

56. The apparatus of claim 37, wherein at least a first symbol of the excluded TTI is configured for communication in an opposite link direction than a link direction of at least some of the plurality of aggregated TTIs.

57. An apparatus for wireless communication at a base station, comprising:

a processor,

memory in electronic communication with the processor; and

instructions stored in the memory and operable, when executed by the processor, to cause the apparatus to:

transmit, from the base station and to a user equipment (UE), control signaling that indicates configuration information corresponding to an excluded aggregated transmission time interval (TTI);

transmit, to the UE, a grant of resources of a communication channel over a plurality of aggregated TTIs;

identify a location of the excluded TTI within the plurality of aggregated TTIs based at least in part on the control signaling; and

communicate with the UE via the resources of the communication channel over at least a subset of the plurality of aggregated TTIs other than the excluded TTI based at least in part on the grant and the location of the excluded TTI.

58. The apparatus of claim 57, wherein the instructions are further executable by the processor to:

adjust an end TTI for the plurality of aggregated TTIs based at least in part on the location of the excluded TTI.

59. The apparatus of claim 57, wherein the instructions are further executable by the processor to:

adjust a TTI number for the plurality of aggregated TTIs based at least in part on the location of the excluded TTI.

60. The apparatus of claim 57, wherein the instructions are further executable by the processor to:

generate a TTI reassignment indication reassigning at least a portion of a first TTI of the plurality of aggregated TTIs.

61. The apparatus of claim 60, wherein the instructions are further executable by the processor to:

adjust TTIs included in the plurality of aggregated TTIs based at least in part on the TTI reassignment indication.

62. The apparatus of claim 61, wherein adjusting the TTIs comprises instructions further executable to:

determine a location of the first TTI within the plurality of aggregated TTIs; and

shift a subset of the plurality of aggregated TTIs, that occurs after the first TTI, back by at least one TTI based at least in part on the determined location.

63. The apparatus of claim 61, wherein the instructions are further executable by the processor to:

identify a first plurality of symbols of the first TTI associated with a synchronization signal to be transmitted via a first transmit beam and a second plurality of symbols of the first TTI to be transmitted via a second transmit beam; and

transmit a first portion of a data transmission of the first TTI in the first plurality of symbols via the first transmit beam and a second portion of the data transmission of the first TTI in the second plurality of symbols via the second transmit beam.

64. The apparatus of claim 61, wherein the instructions are further executable by the processor to:

receive a merged feedback message that includes channel state information (CSI) and acknowledgement data.

65. The apparatus of claim 60, wherein generating the TTI reassignment indication comprises instructions further executable to:

generate the TTI reassignment indication based at least in part on determining that a capability of the UE satisfies a threshold; and

transmit the TTI reassignment indication to the UE.

66. The apparatus of claim 65, wherein determining that the capability of the UE satisfies the threshold comprises instructions further executable to:

determine that a response time of the UE satisfies the threshold.

67. The apparatus of claim 60, wherein the instructions are further executable by the processor to:

receive an acknowledgment of the TTI reassignment indication prior to a beginning TTI of the plurality of aggregated TTIs.

68. The apparatus of claim 60, wherein the instructions are further executable by the processor to:

communicate a transport block size that excludes the first TTI from a calculation of the transport block size.

69. The apparatus of claim 60, wherein the instructions are further executable by the processor to:

determine that the at least the portion of the first TTI is being punctured.

70. The apparatus of claim 57, wherein the grant comprises a bit sequence identifying the plurality of aggregated TTIs.

71. The apparatus of claim 57, wherein the grant comprises an index that corresponds to one of a plurality of configurations for the plurality of aggregated TTIs.

72. The apparatus of claim 57, wherein at least some of the plurality of aggregated TTIs are non-contiguous in time.

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